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ATMOSPHERIC TRANSMITTANCE CURVES FOR SEVERAL METEOROLOGICAL CONDITIONS

25 March 1963

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by

M. W. Harper

Electro-Optical Branch
Electromagnetics Laboratory
Directorate of Research and Development
U. S. Army Missile Command
Redstone Arsenal, Alabama

ABSTRACT

This report is intended to provide a tool for use in designing infrared systems, and is not a theoretical treatise on atmospheric effects in optical transmission.

Spectral transmission curves are furnished for several different combinations of atmospheric conditions and ranges. These infrared spectral transmission curves were calculated assuming the earth to be flat for the ranges of interest, and assuming the infrared systems to be at sea level.

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I. INTRODUCTION

During the course of calculating infrared spectral transmission values, it became clear that some means was needed to obtain these spectral transmission values more quickly. This report is intended to provide a tool for use in designing infrared systems, and is not a theoretical treatise on atmospheric effects in optical transmission. This report furnishes spectral transmission curves for several different combinations of atmospheric conditions and ranges.

These infrared spectral transmission curves were calculated assuming the earth to be flat for the ranges of interest, and assuming the infrared systems to be at sea level.

II. DISCUSSION

The main factors in atmospheric infrared attenuation are absorption by water vapor, carbon dioxide, ozone, and scattering by airborne particles. The water vapor content (Figure 1) of the atmosphere is weather-dependent. Thus, either the amount of water vapor between the target and observer (the optical thickness) must be known for a particular problem, or an average-weather assumption must be made. For simplicity of calculations, average-day values and bad-day values were assumed for water vapor content and visibility. The carbon dioxide content of the atmosphere was taken to be 3.2×10^{-4} parts per unit volume of air. The ozone content of the atmosphere was taken to be .002 mm per kilometer.

The scattering coefficient of transmission has to be calculated as a function of wavelength, range and visibility $\left[T_{si} = e^{-\frac{3.91}{V}\left(\frac{\lambda i}{.55}\right)^{-q} R}\right]$ where

T_{si} = Transmission due to scattering at wavelength (i).
V = Visibility (kilometers)
q = $.585\ V^{1/3}$
i = Wavelength (microns)
R = Range (kilometers)

This relationship enables us to compute the transmission at the midpoint of window i for any value of R if the visibility is known.

(Sample Calculation)

$$V = 5 \text{ km}, \quad q = 1.0, \quad i = 1 \text{ micron}, \quad R = 3 \text{ km}$$

$$T_{si} = e^{-\frac{3.91}{V}\left(\frac{\lambda_i}{.55}\right)^{-q} R}$$

$$T_{s(1\mu)} = e^{-\frac{3.91}{5}\left(\frac{1.0}{.55}\right)^{-1.0}(3)}$$

$$= e^{-.782\left(\frac{.55}{1.0}\right)(3)}$$

$$= e^{-1.29}$$

$$= .275$$

Precipitable H_2O is taken from Figure 1 of this report. With 90% relative humidity and 100°F. temperature, there is 1 mm H_2O for every 75 feet of path length. Dividing range by this factor gives the total precipitable H_2O for a 3-km range.

$$\text{Total Precipitable } H_2O = \frac{\text{Range (feet)}}{\text{feet/mm precipitable } H_2O}$$

$$= \frac{9842 \text{ feet}}{75 \text{ feet/1 mm}}$$

$$= 131.22 \text{ mm}$$

Transmission due to absorption by water vapor is plotted as a function of precipitable H_2O versus wavelength, as shown in Figure 8, Reference 7. Knowing that the precipitable H_2O is 13.1 cm, $T_{H_2O(1\mu)}$ is .64.

Transmission due to absorption by carbon dioxide is plotted as a function of range versus wavelength (Figure 17, Reference 7). Knowing the range is 3 km, $T_{CO_2(1\mu)}$ is 100%.

From Figure 7, Reference 7, there is .002 mm of ozone at STP per kilometer at sea level. The total amount of ozone for XKM range equals the product of XKM and ZM.M of ozone.

$$\text{Total ozone for 3-km range} = 3 \text{ km} \cdot .002 \text{ mm/km}$$
$$= .006 \text{ mm}$$

Knowing the amount of ozone in the path length, the transmission due to absorption by ozone is 100% at one micron (Figure 23, Reference 7).

After the coefficients of transmission due to absorption by water vapor, carbon dioxide, ozone, and scattering have been found, the atmospheric transmission is calculated as the product of these functions:

$$T_{a}(\lambda) = T_{H_2O}(\lambda) \cdot T_{CO_2}(\lambda) \cdot T_{O_3}(\lambda) \cdot T_{si}$$

$$T_a(1.0_\mu) = (.64) \cdot (1.00) \cdot (1.00) \cdot (.28)$$

$$= .18$$

$$= 18\%$$

III. CONCLUSIONS AND RECOMMENDATIONS

Value for $T_{H_2O}(\lambda)$, $T_{O_3}(\lambda)$, $T_{CO_2}(\lambda)$, and T_{si} were calculated at one-tenth micron intervals. The resolution of the transmission curves is, therefore, not much better than ± .1 micron. Moreover, the apparent smoothing of the curves used as source material for this report (Reference 7) suggests that the results be applied judiciously, especially for very narrowband applications. It should be remembered that the atmospheric conditions considered herein are highly generalized and worst-case conditions may reduce transmission far below the values shown.

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Table I.

SAMPLE CALCULATED DATA

CALCULATED VALUES FOR $T_{H_2O(\lambda)}$, $T_{CO_2(\lambda)}$, $T_{O_3(\lambda)}$, T_{si} AND $T_{a(\lambda)}$

METEOROLOGICAL CONDITIONS:

TEMPERATURE - 100°F RELATIVE HUMIDITY - 90% RANGE - 3-km

VISIBILITY - 5-km PRECIPITABLE H_2O - 13.1-cm

Wavelength Micron	$T_{H_2O(\lambda)}$ Decimal	x	$T_{CO_2(\lambda)}$ Decimal	x	$T_{O_3(\lambda)}$ Decimal	x	T_{si} Decimal	=	$T_{a(\lambda)}$ Decimal
.4	.34		1.00		1.00		.041		.014
.5	.50		1.00		1.00		.08		.04
.6	.89		1.00		1.00		.12		.10
.7	.90		1.00		1.00		.16		.14
.8	.60		1.00		1.00		.20		.12
.9	.11		1.00		1.00		.24		.02
1.0	.64		1.00		1.00		.28		.18
1.1	.16		1.00		1.00		.31		.05
1.2	.33		1.00		1.00		.34		.11
1.3	.00		1.00		1.00		.37		.00
1.4	.00		.98		1.00		.40		.00
1.5	.85		.99		1.00		.42		.36
1.6	.98		.98		1.00		.45		.41
1.7	.93		.99		1.00		.47		.44
1.8	.00		1.00		1.00		.48		.00
1.9	.04		1.00		1.00		.51		.02
2.0	.45		.89		1.00		.52		.21
2.1	.86		.99		1.00		.54		.46
2.2	.93		1.00		1.00		.56		.52
2.3	.86		1.00		1.00		.57		.49
2.4	.35		1.00		1.00		.59		.21
2.5	.00		1.00		1.00		.59		.00

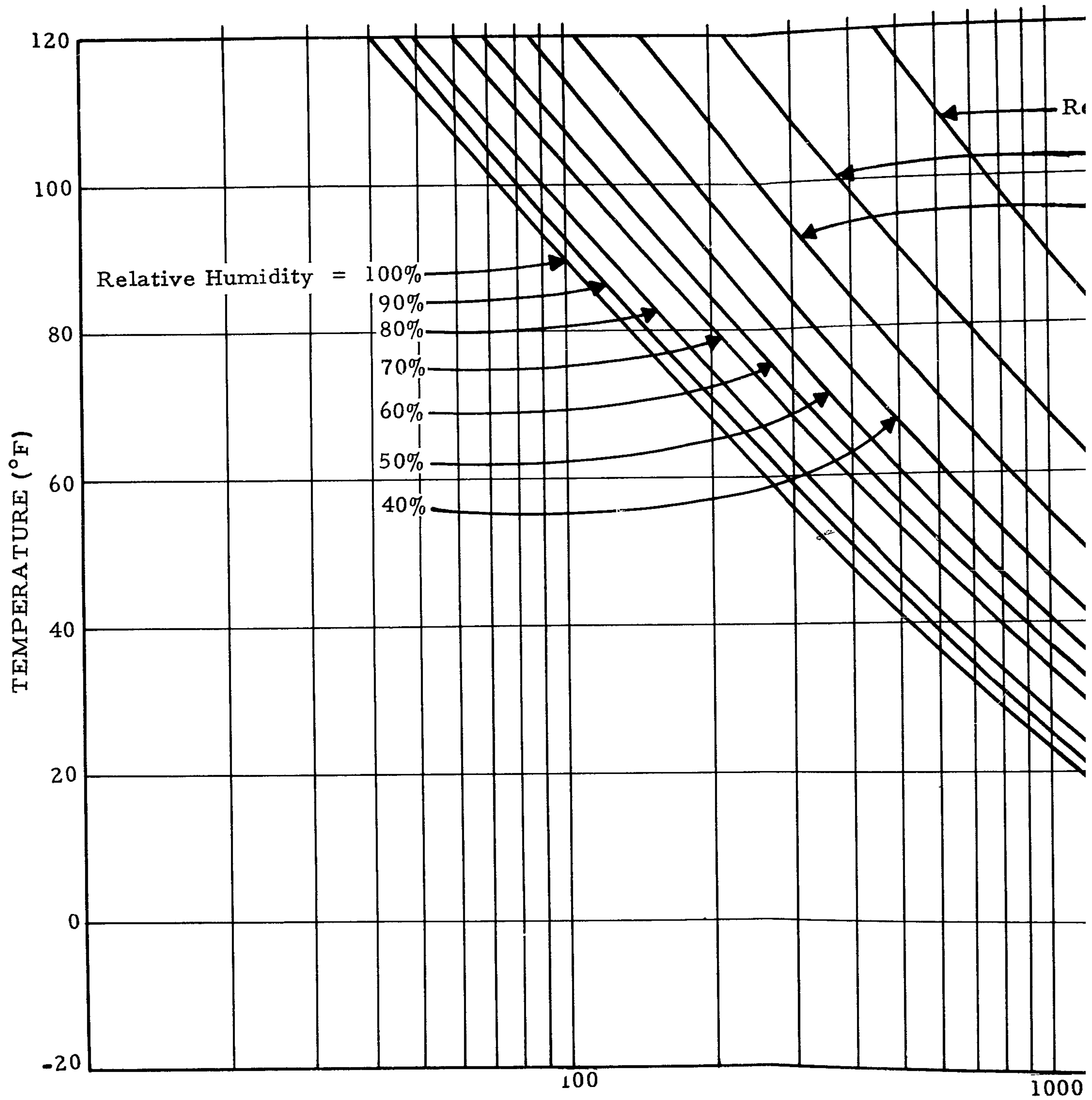
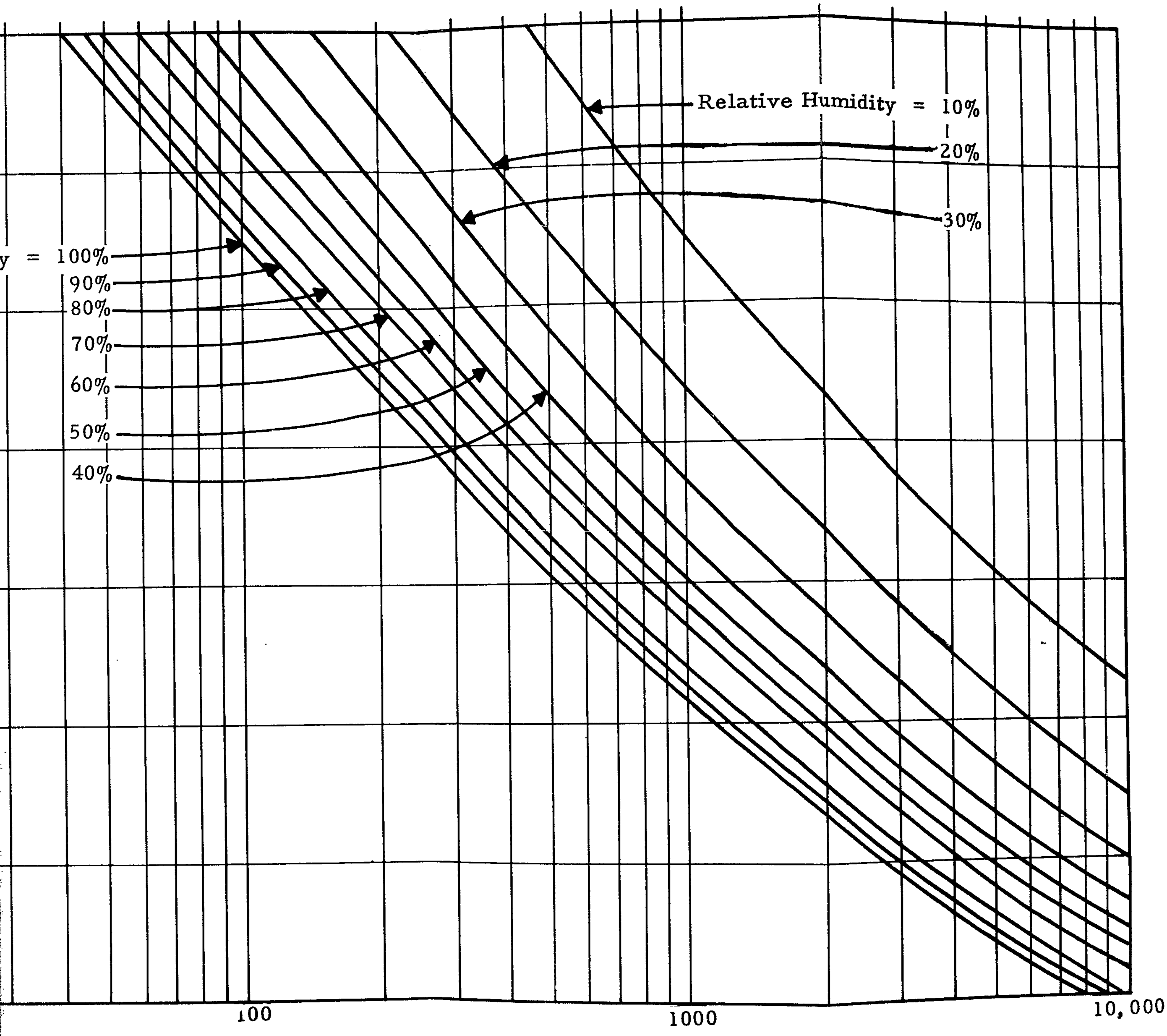


**Figure 1. PATH FOR 1 MM OF WATER (FT/MM



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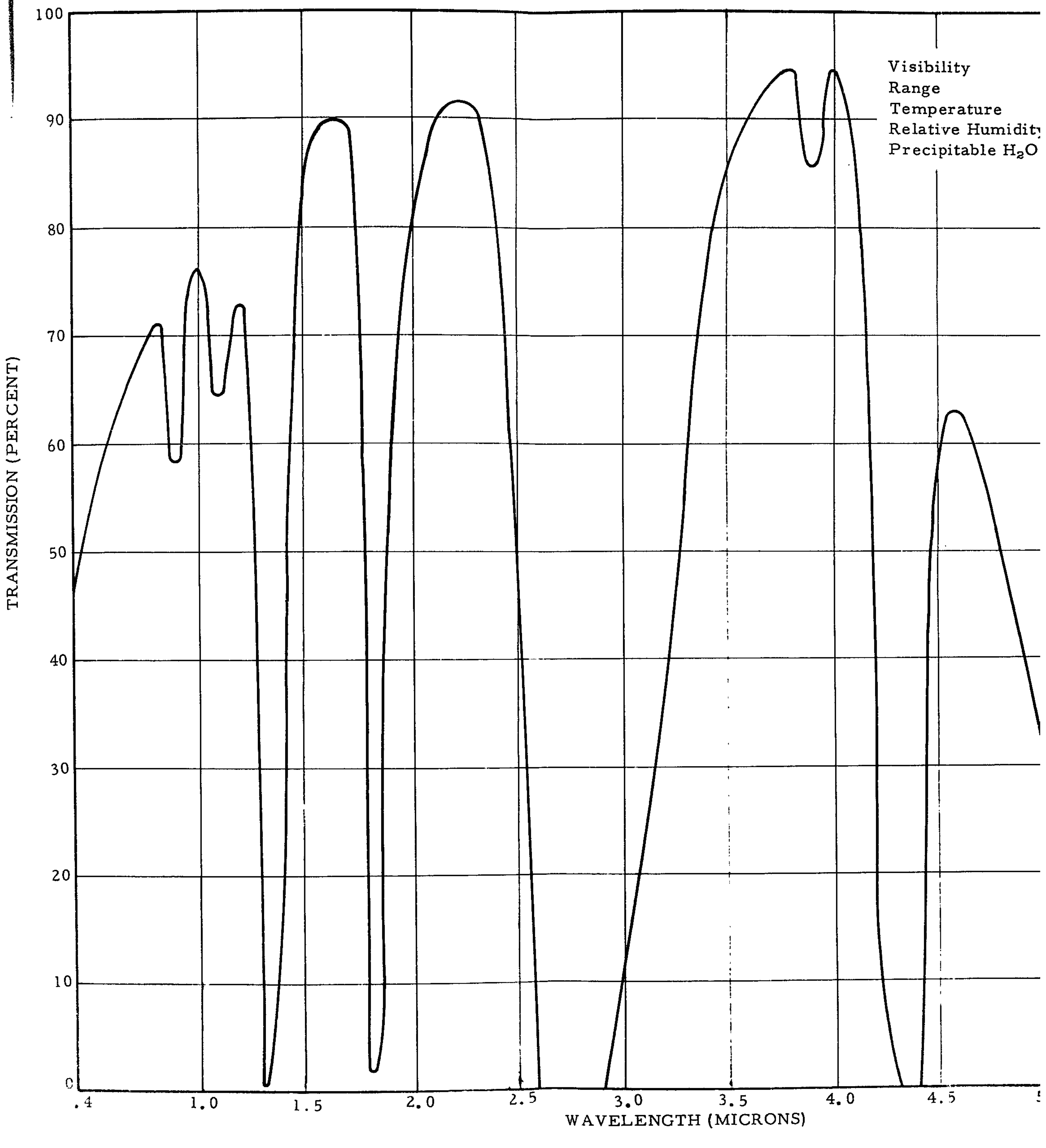
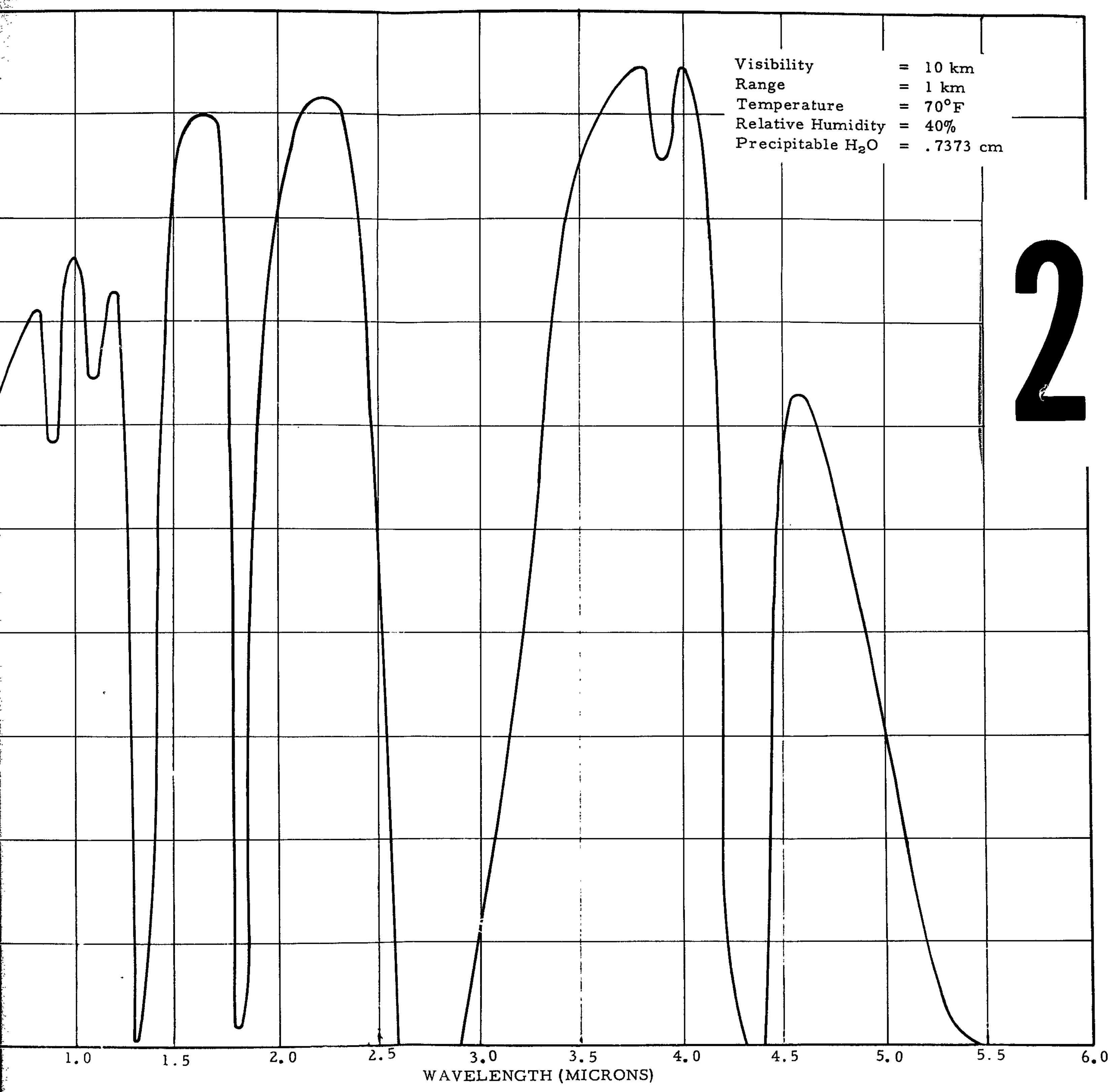


Figure 2. ATMOSPHERIC TRANSMISSION CURVE



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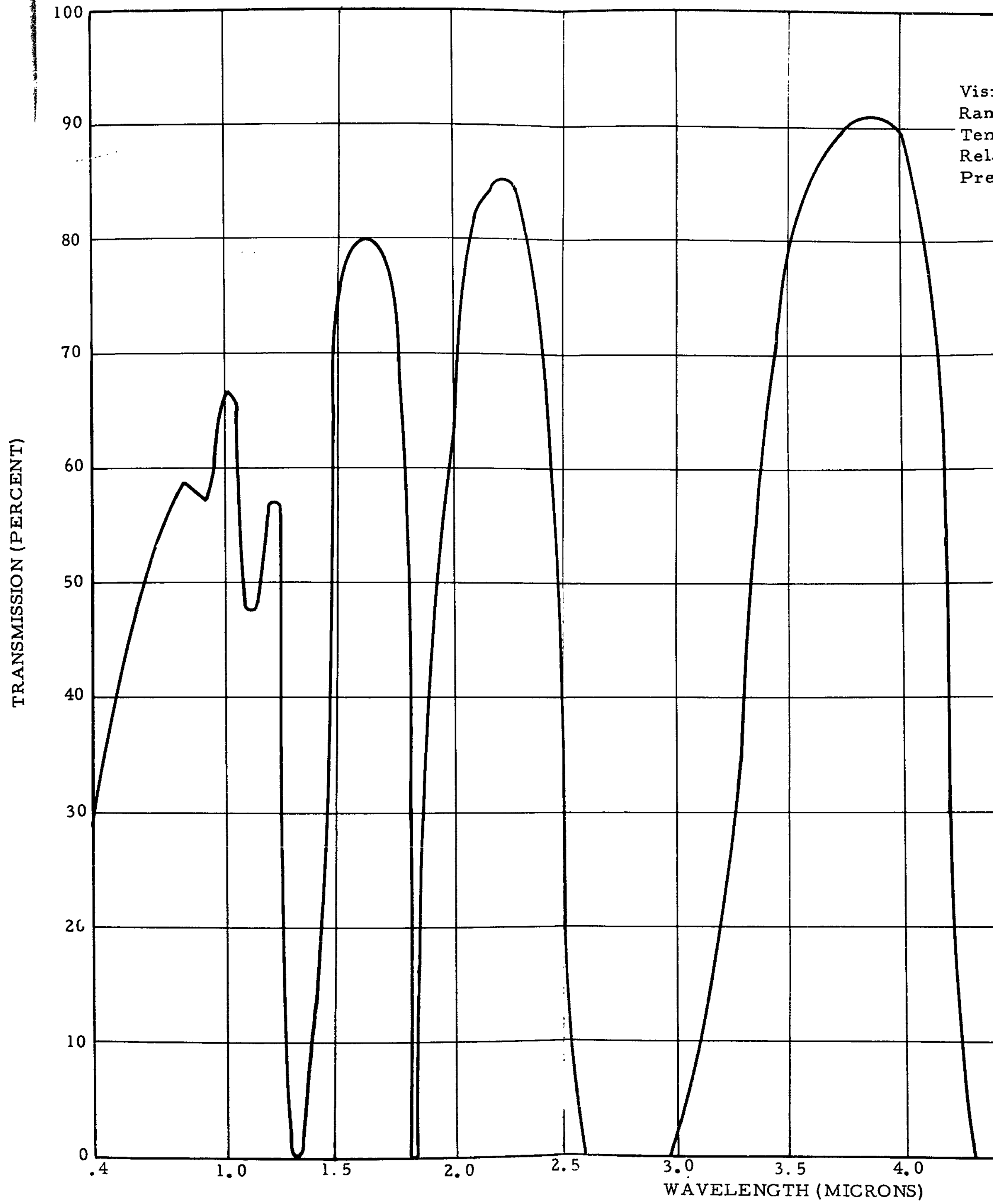

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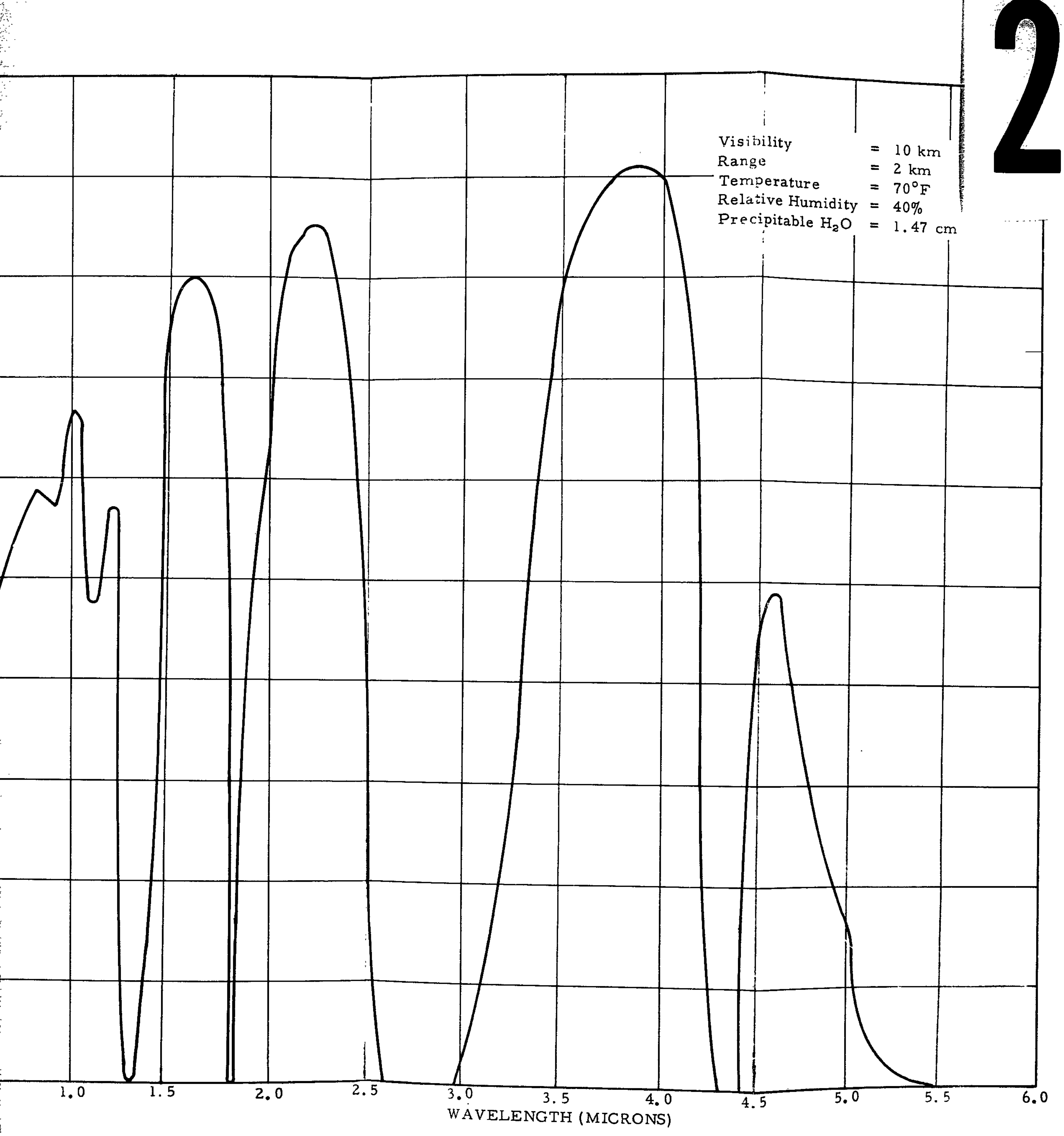

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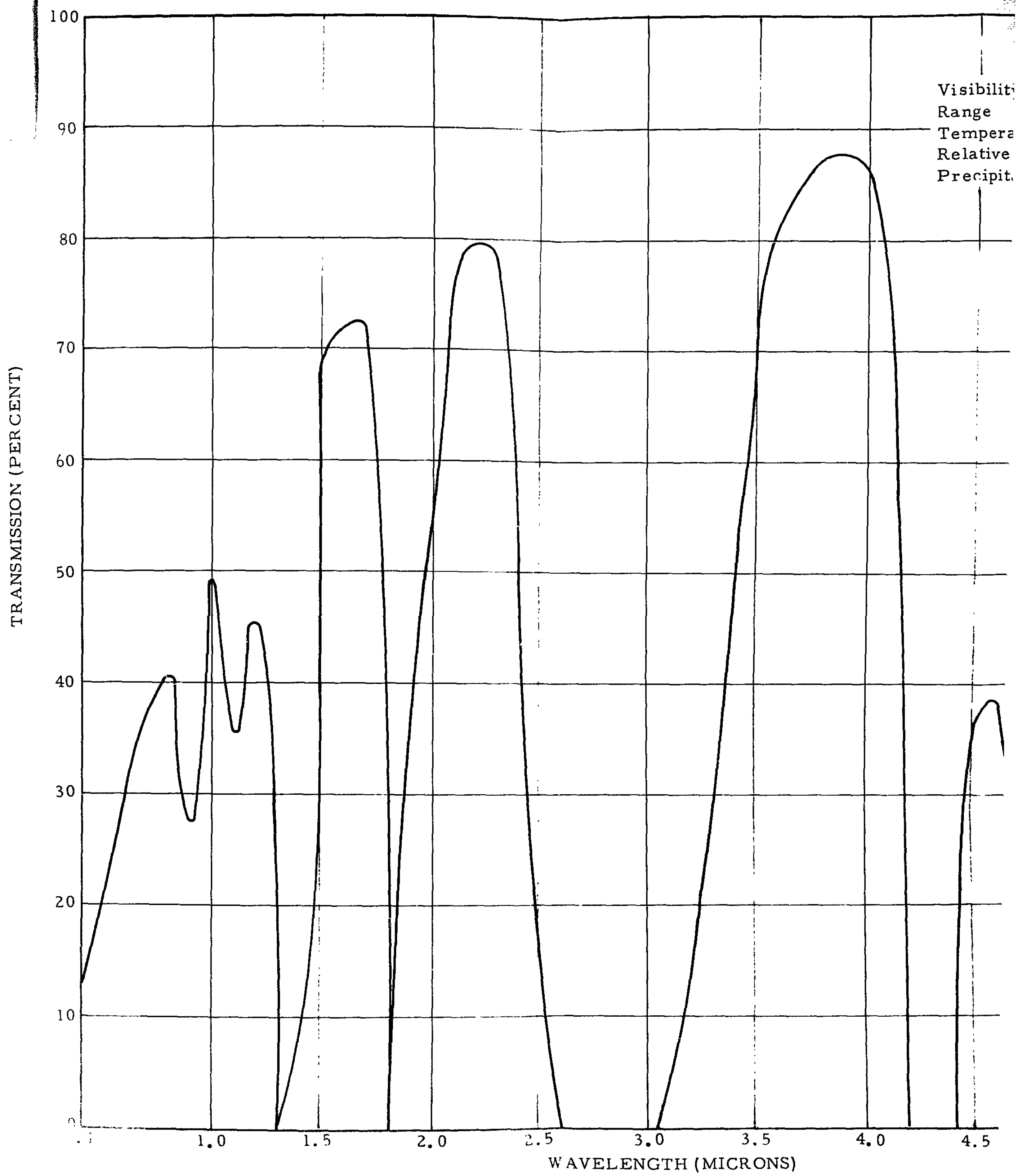

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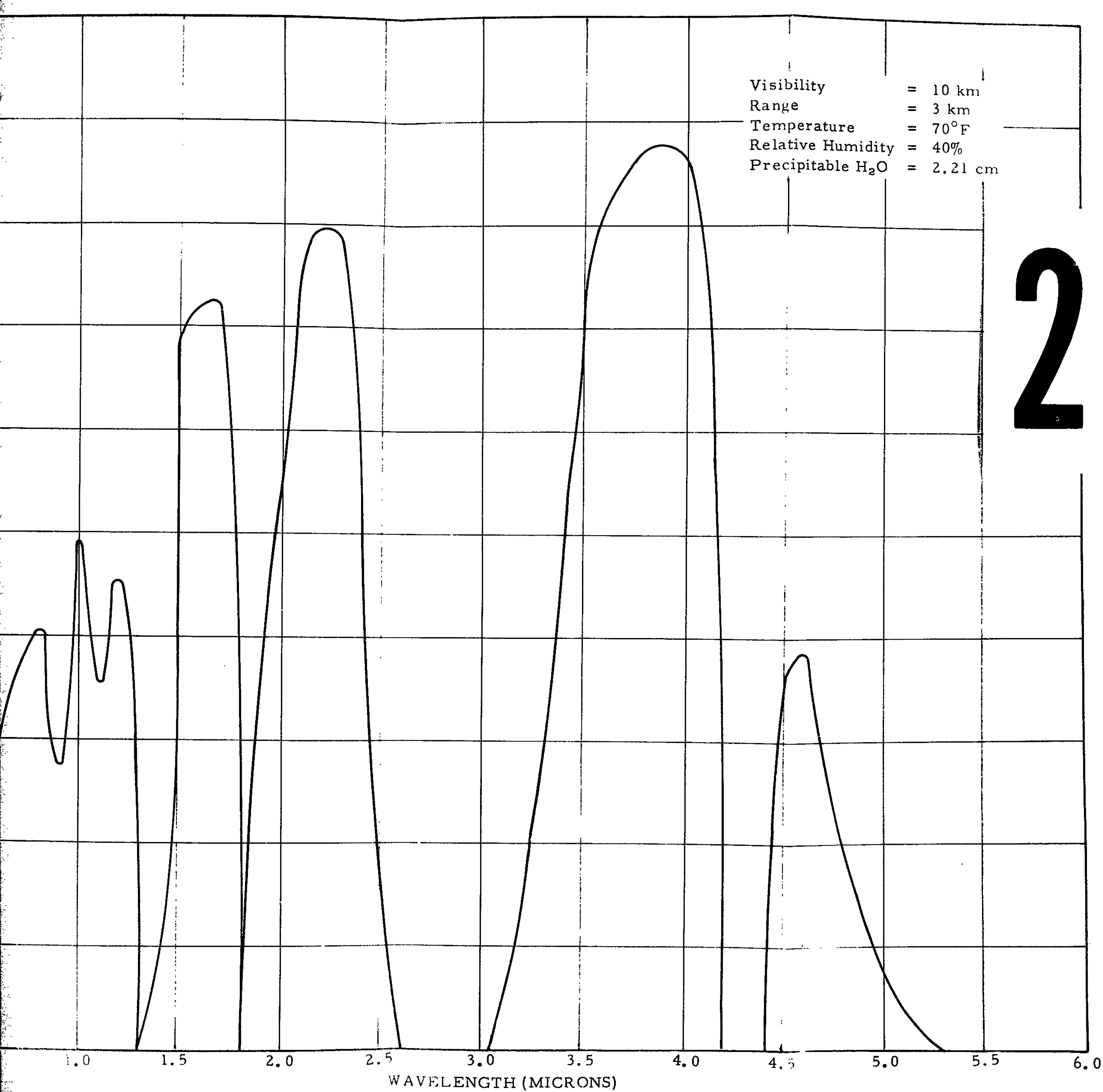

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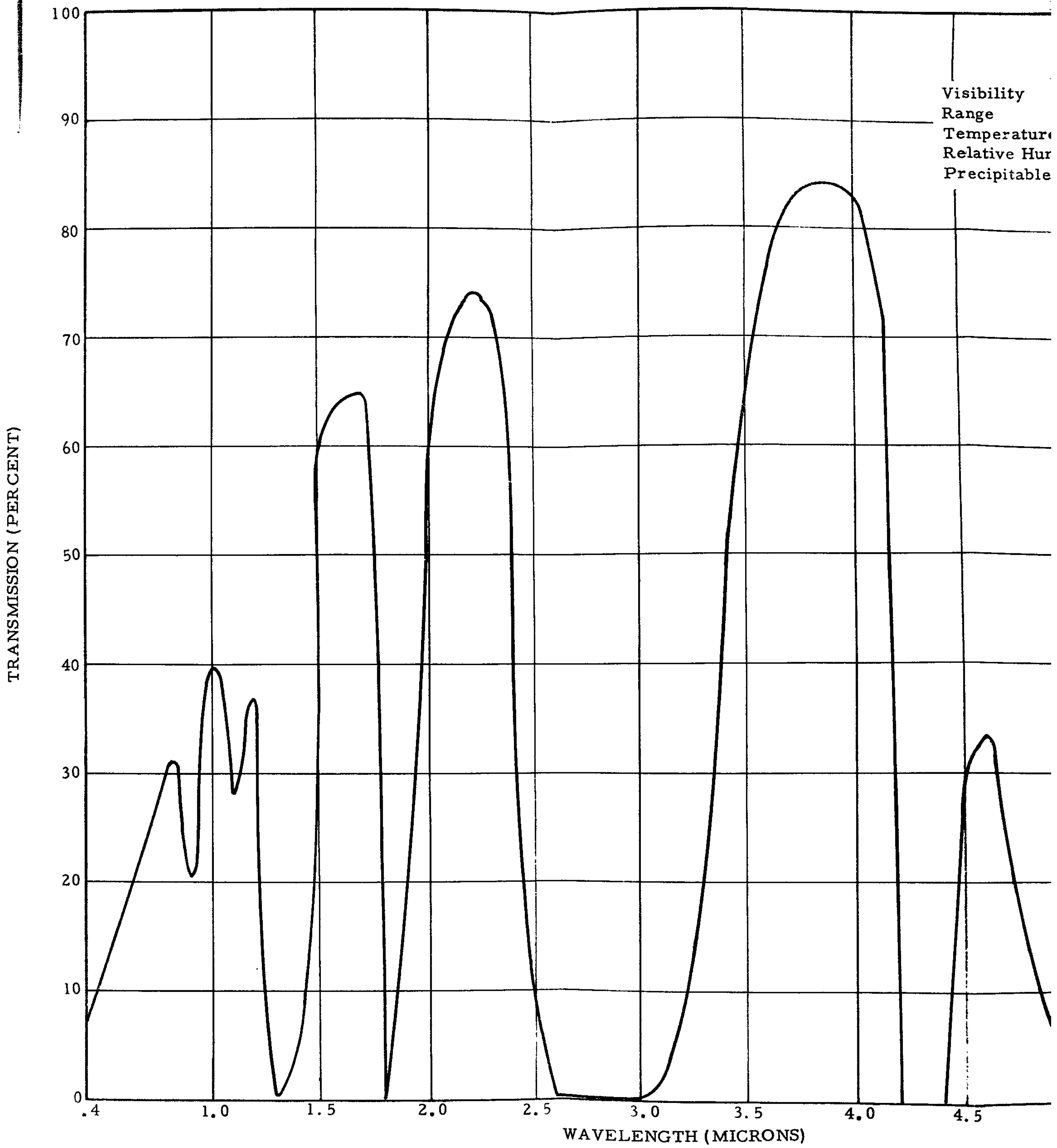

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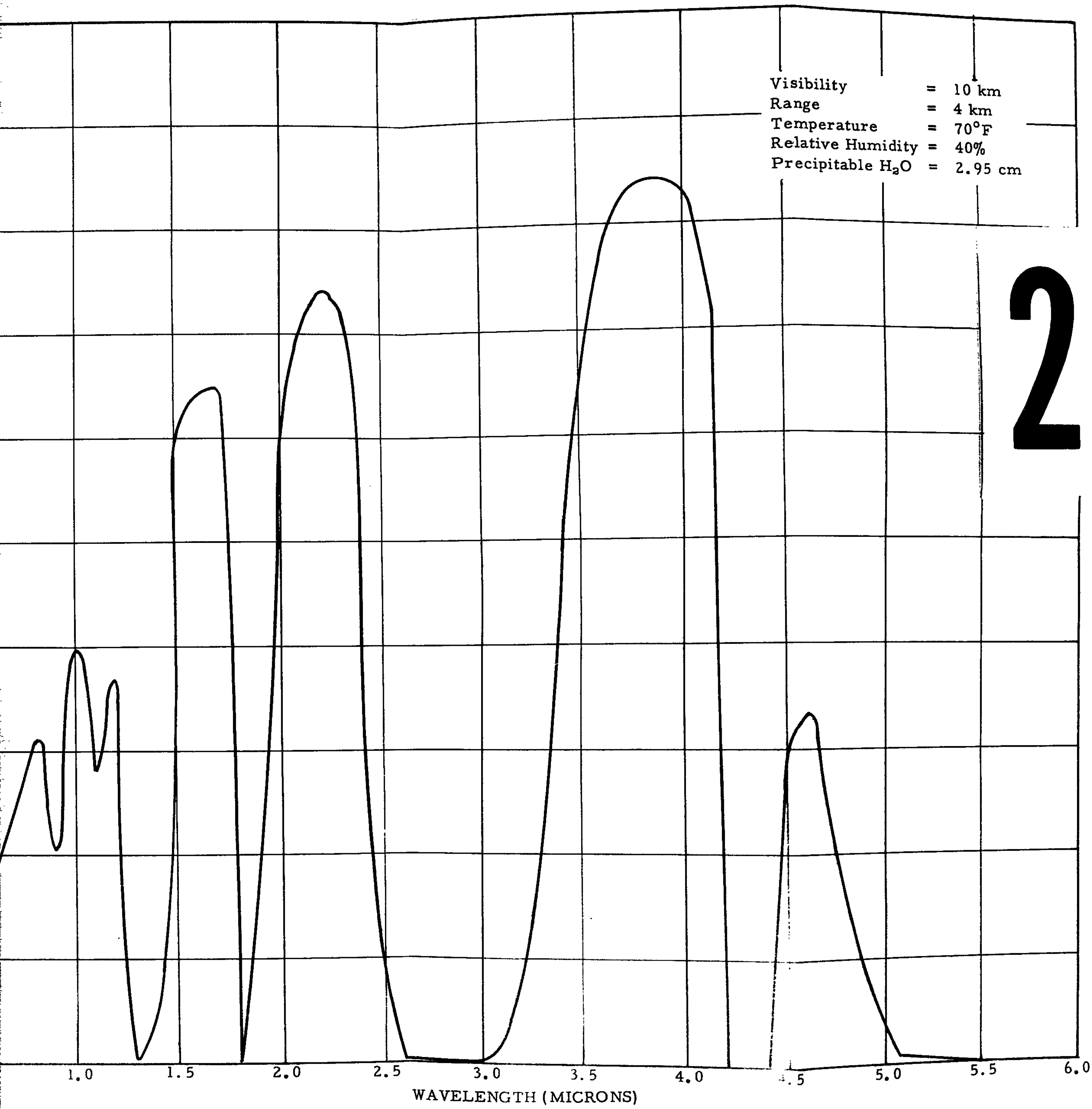

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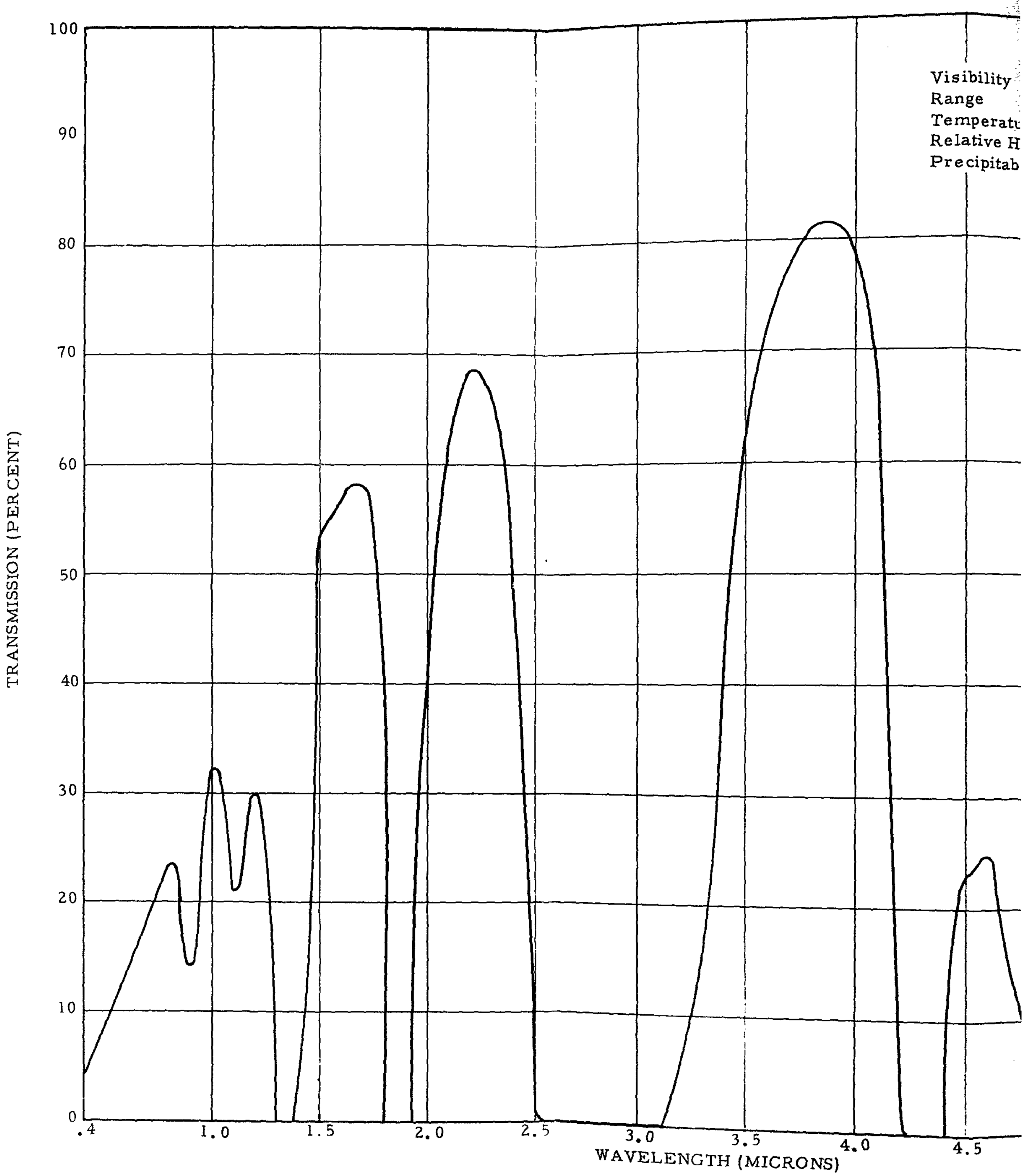

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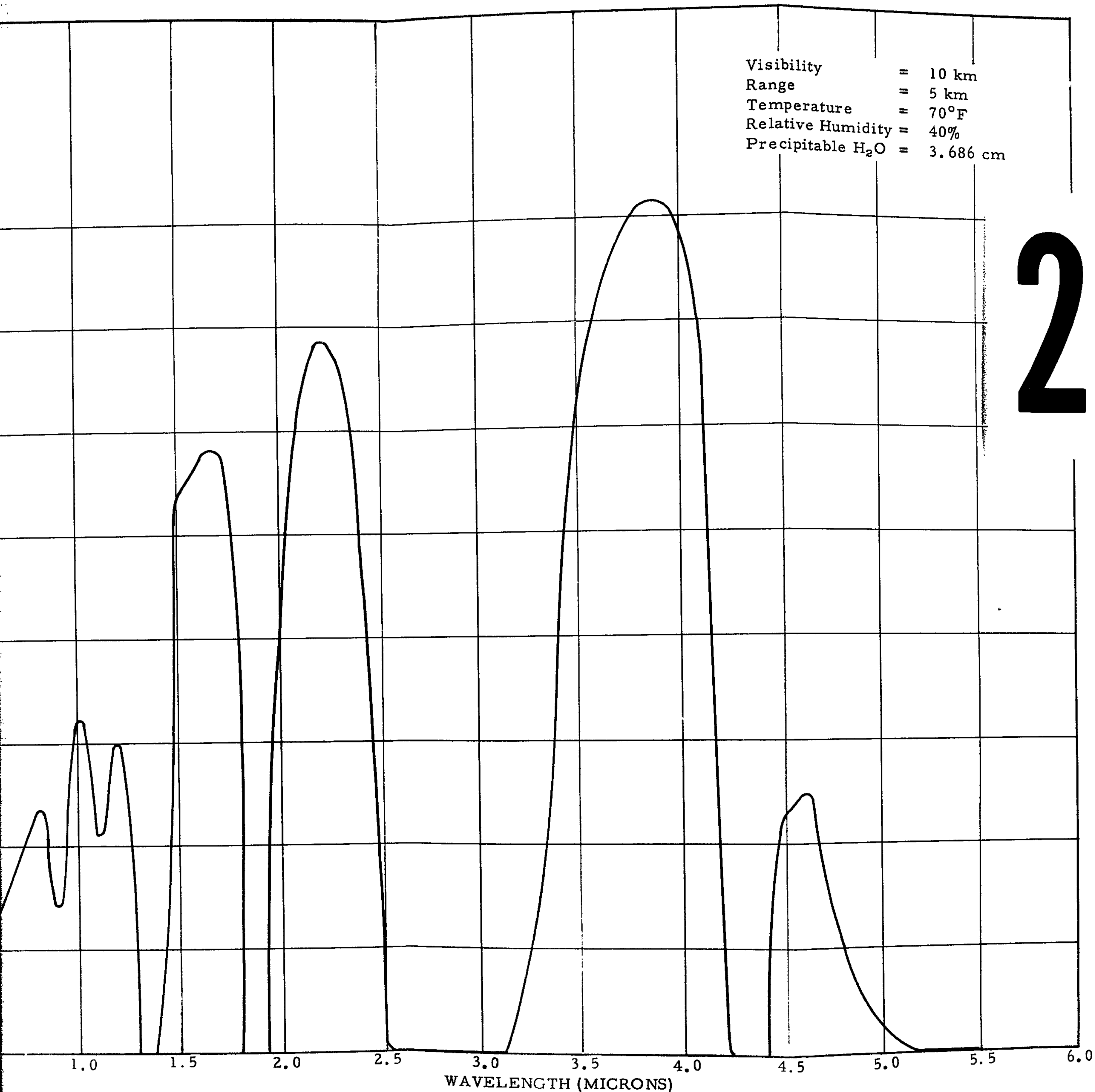

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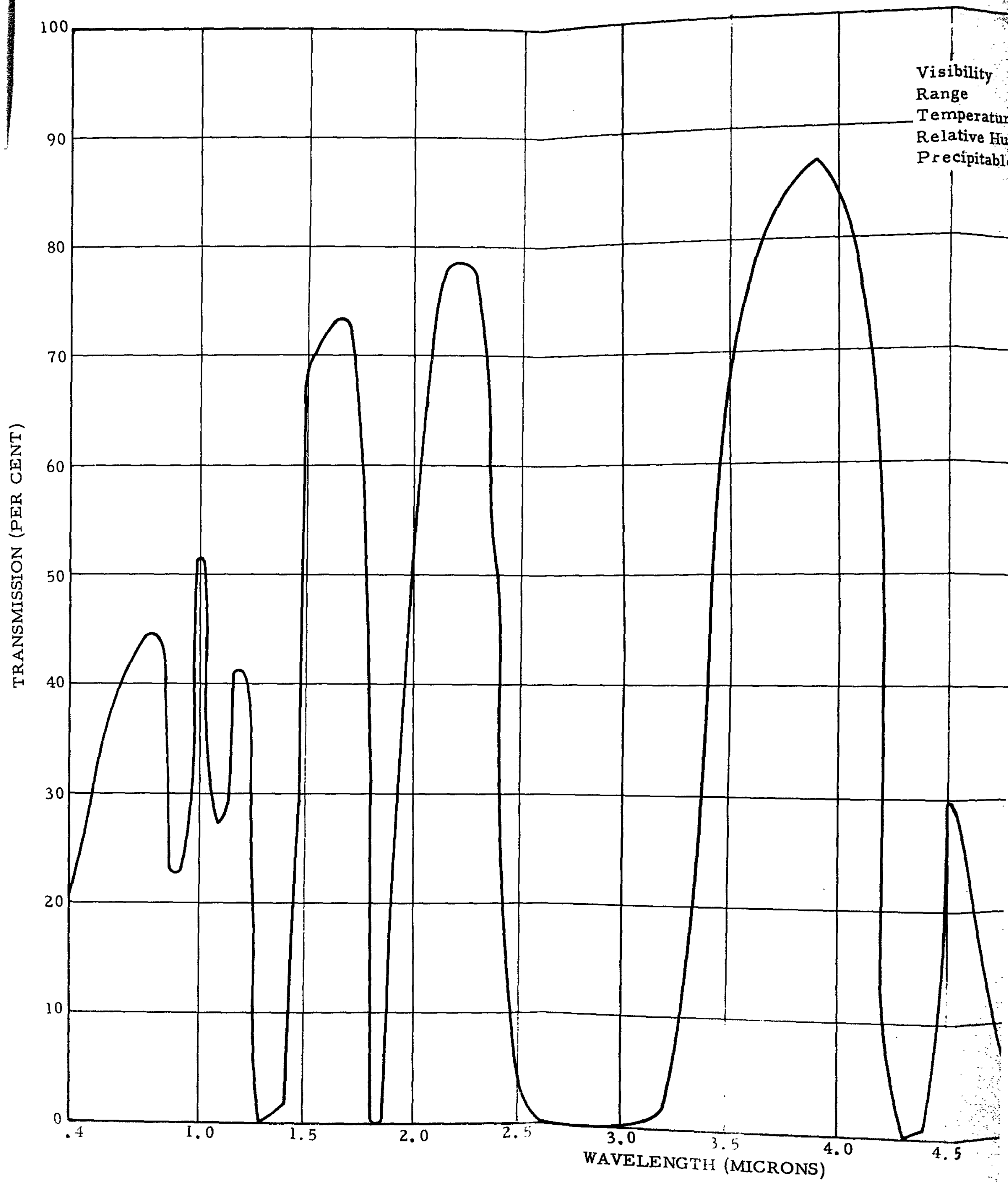

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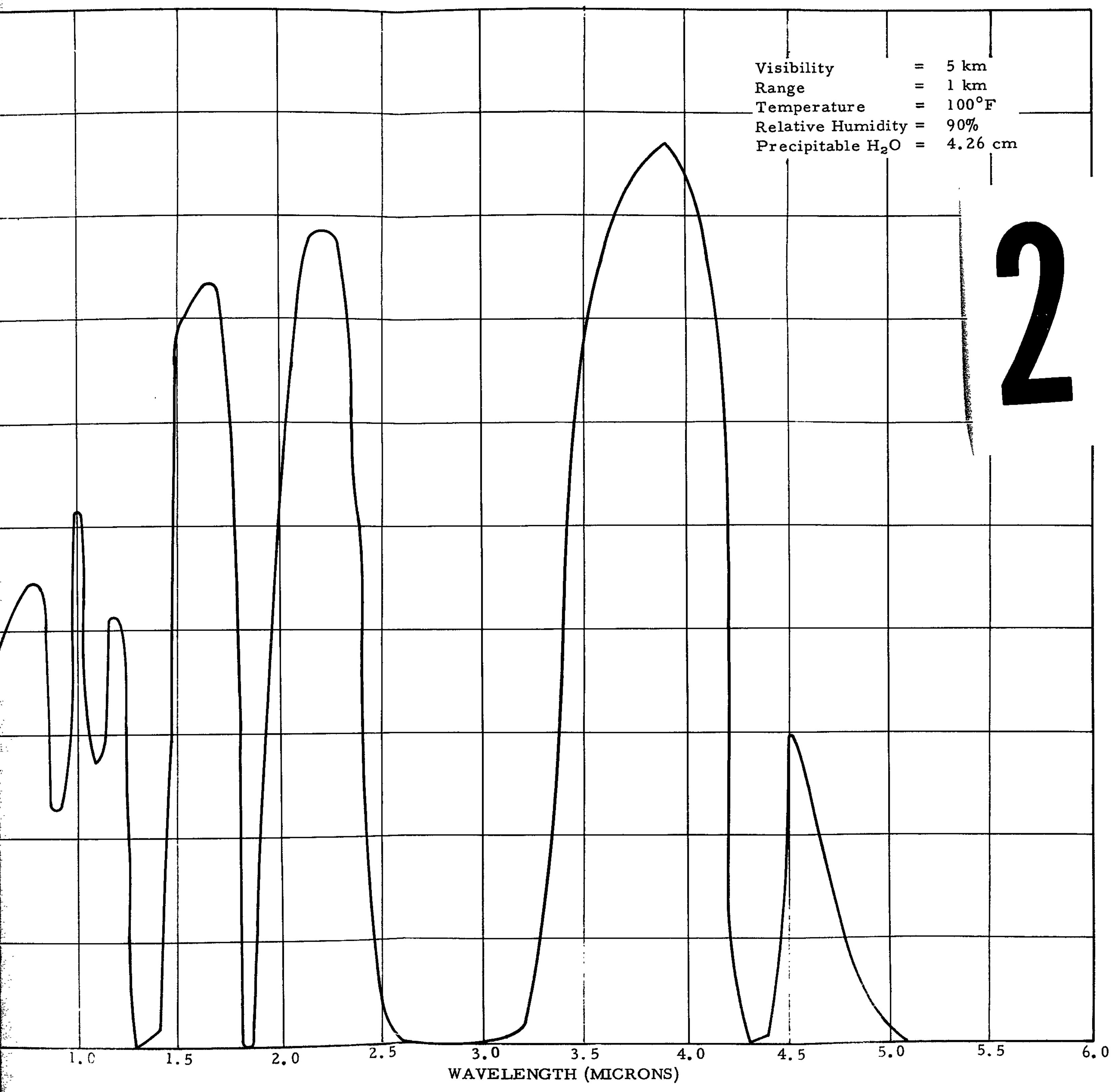

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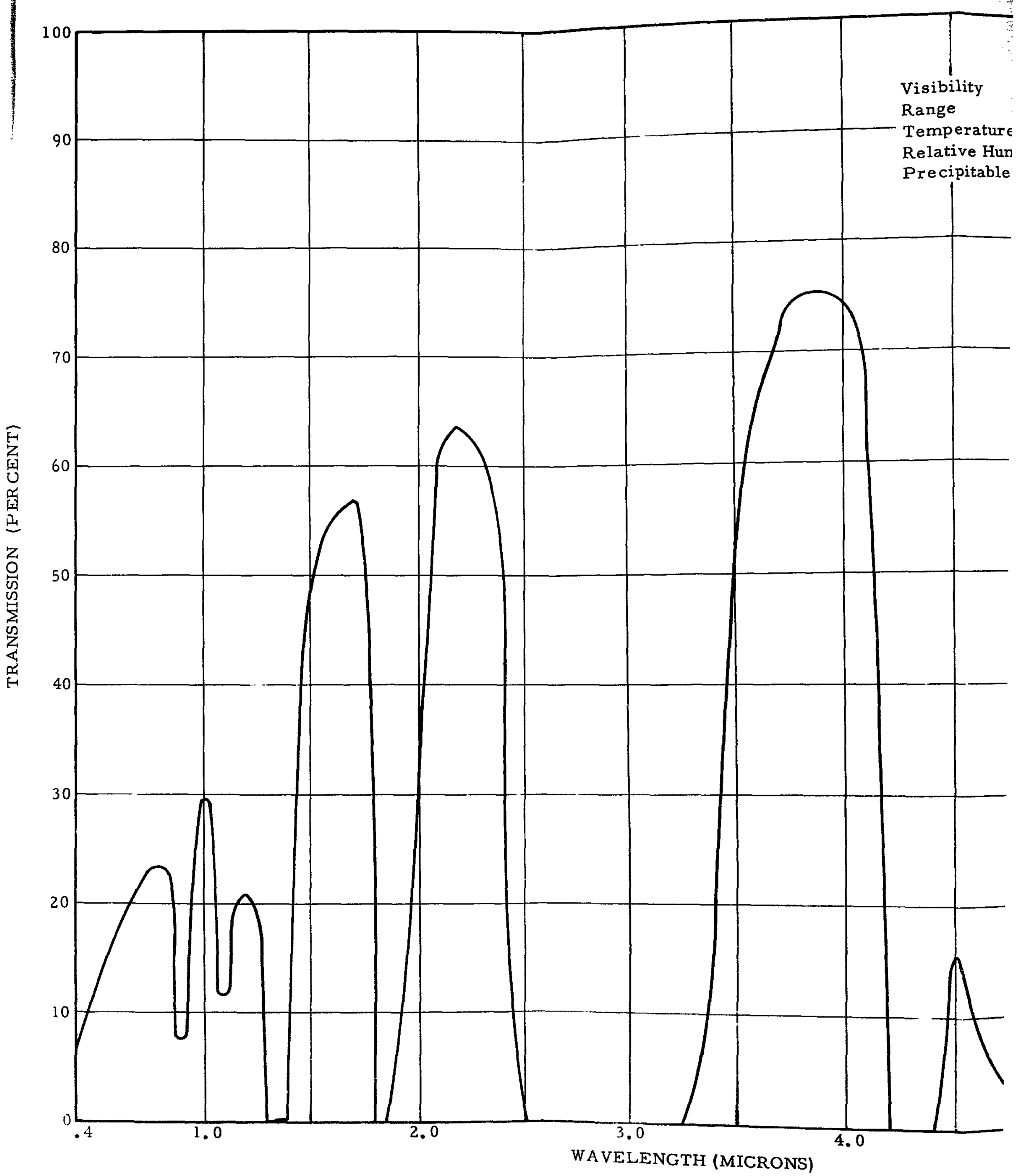

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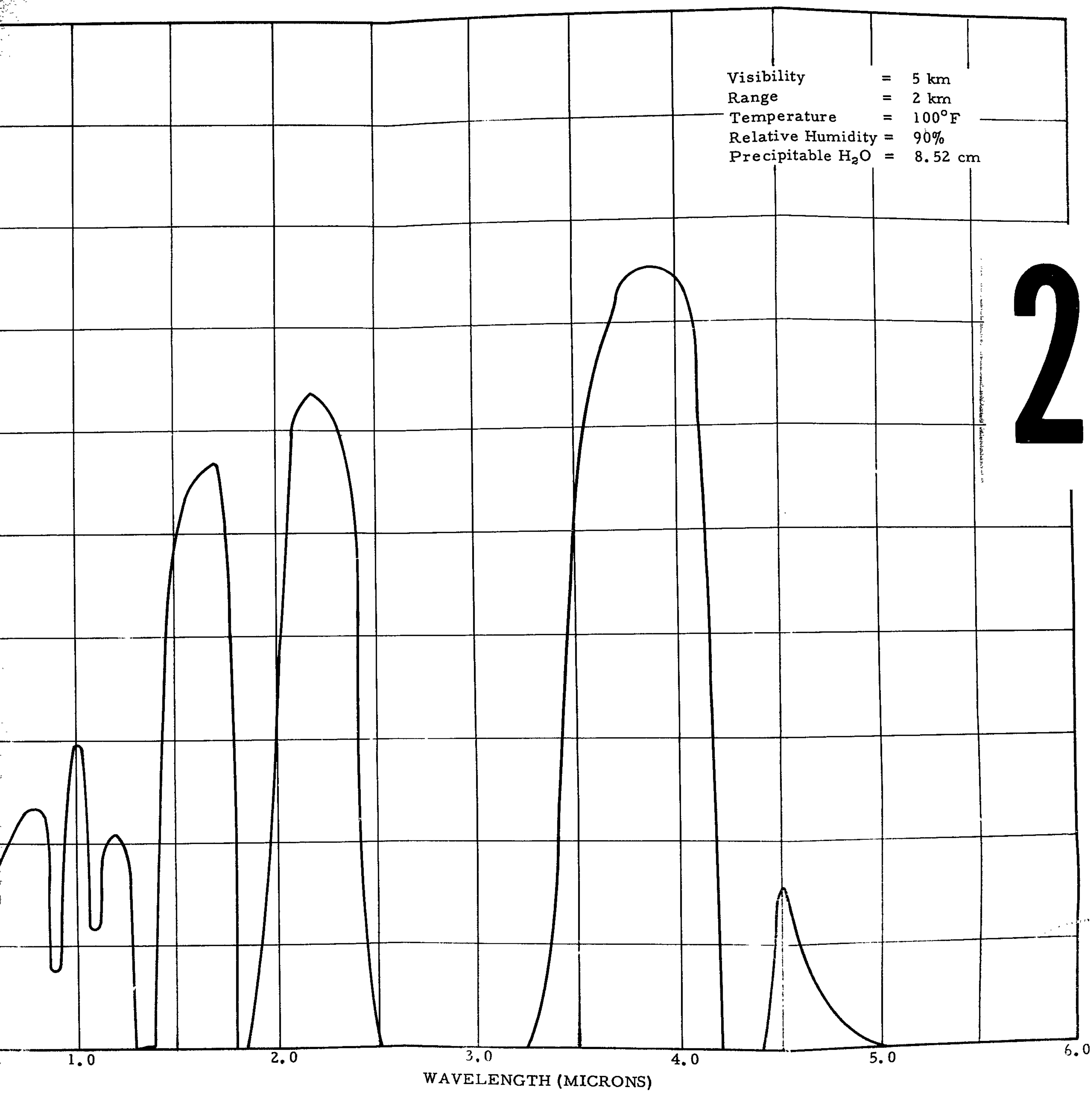

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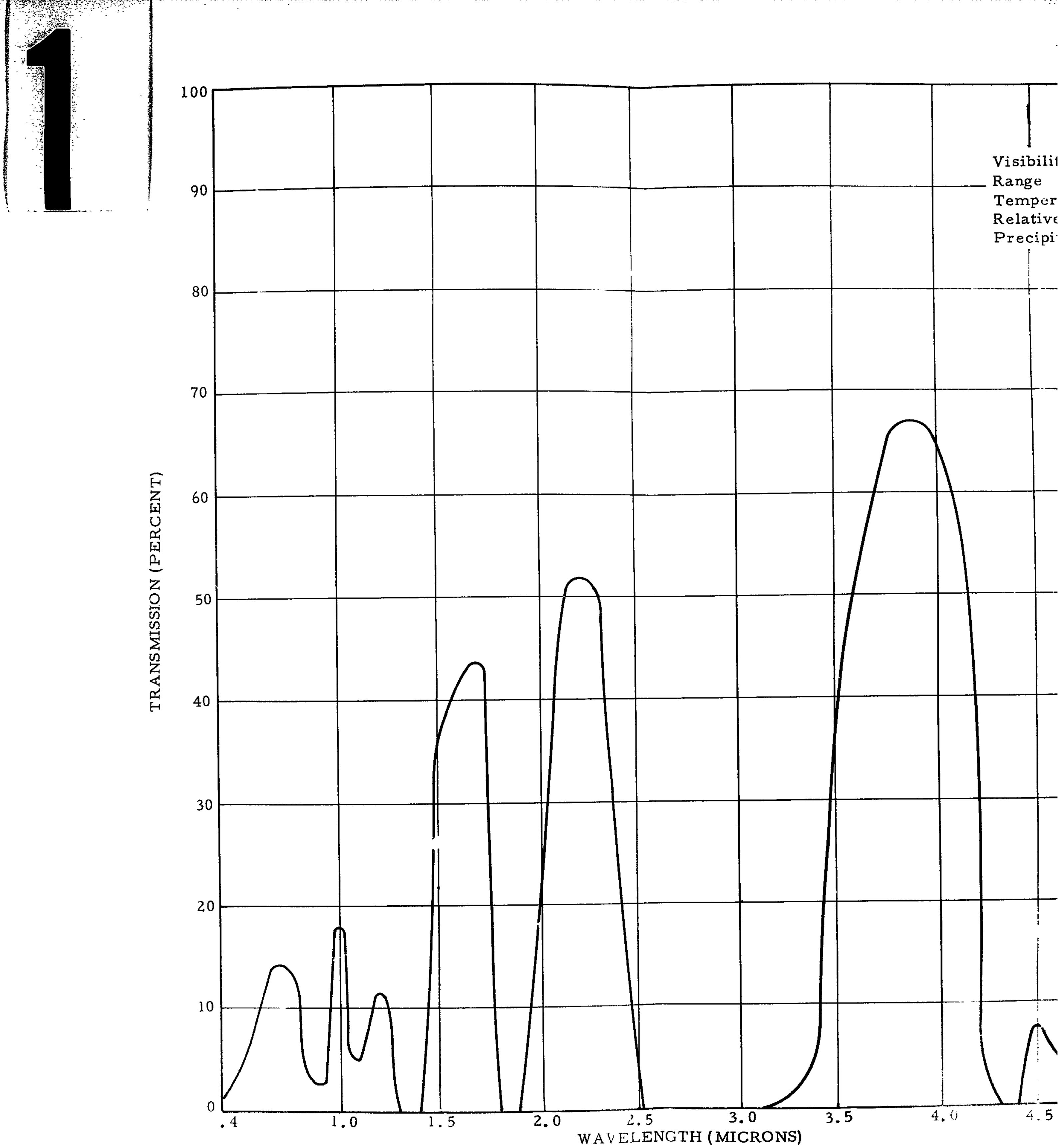

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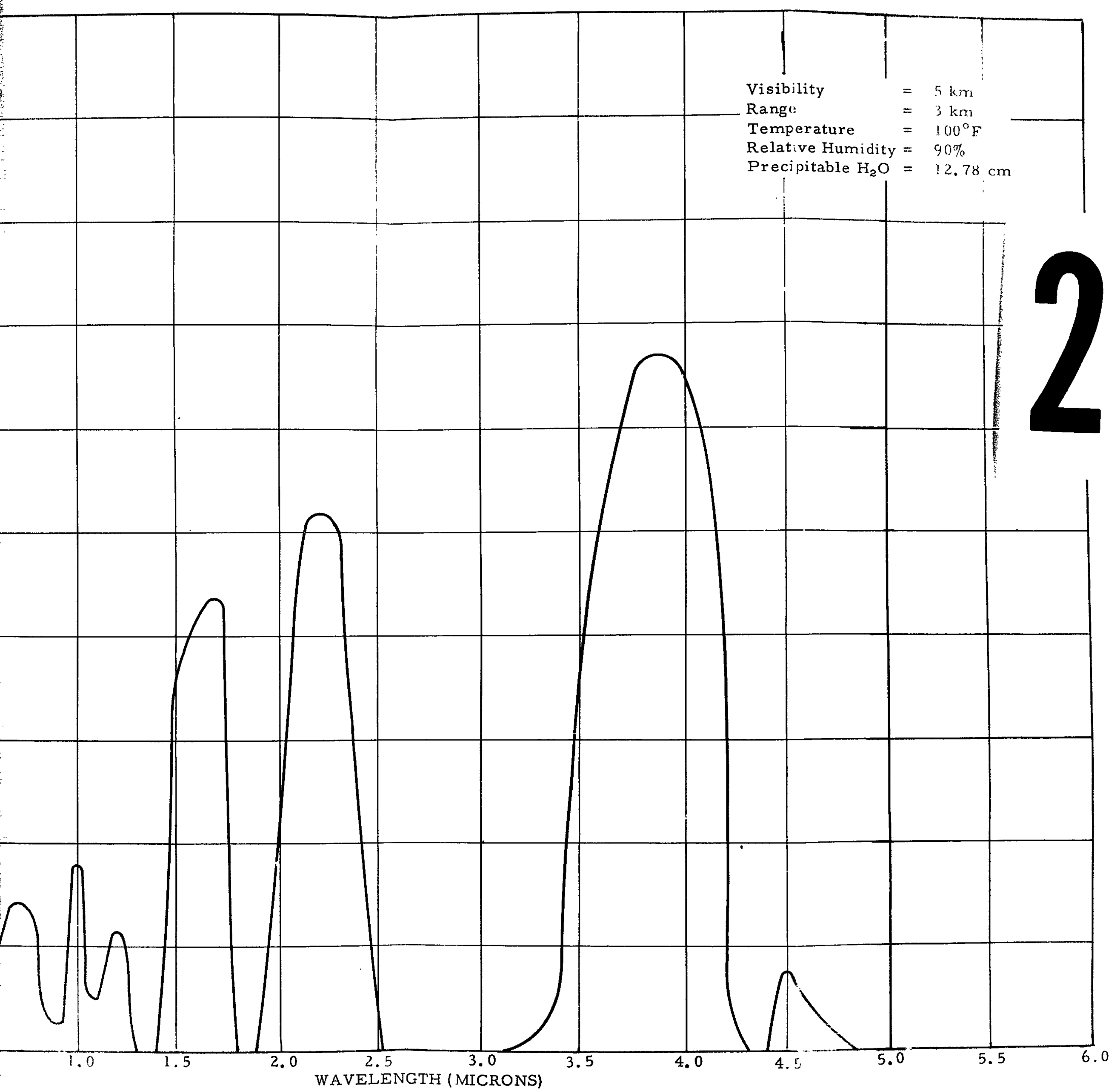

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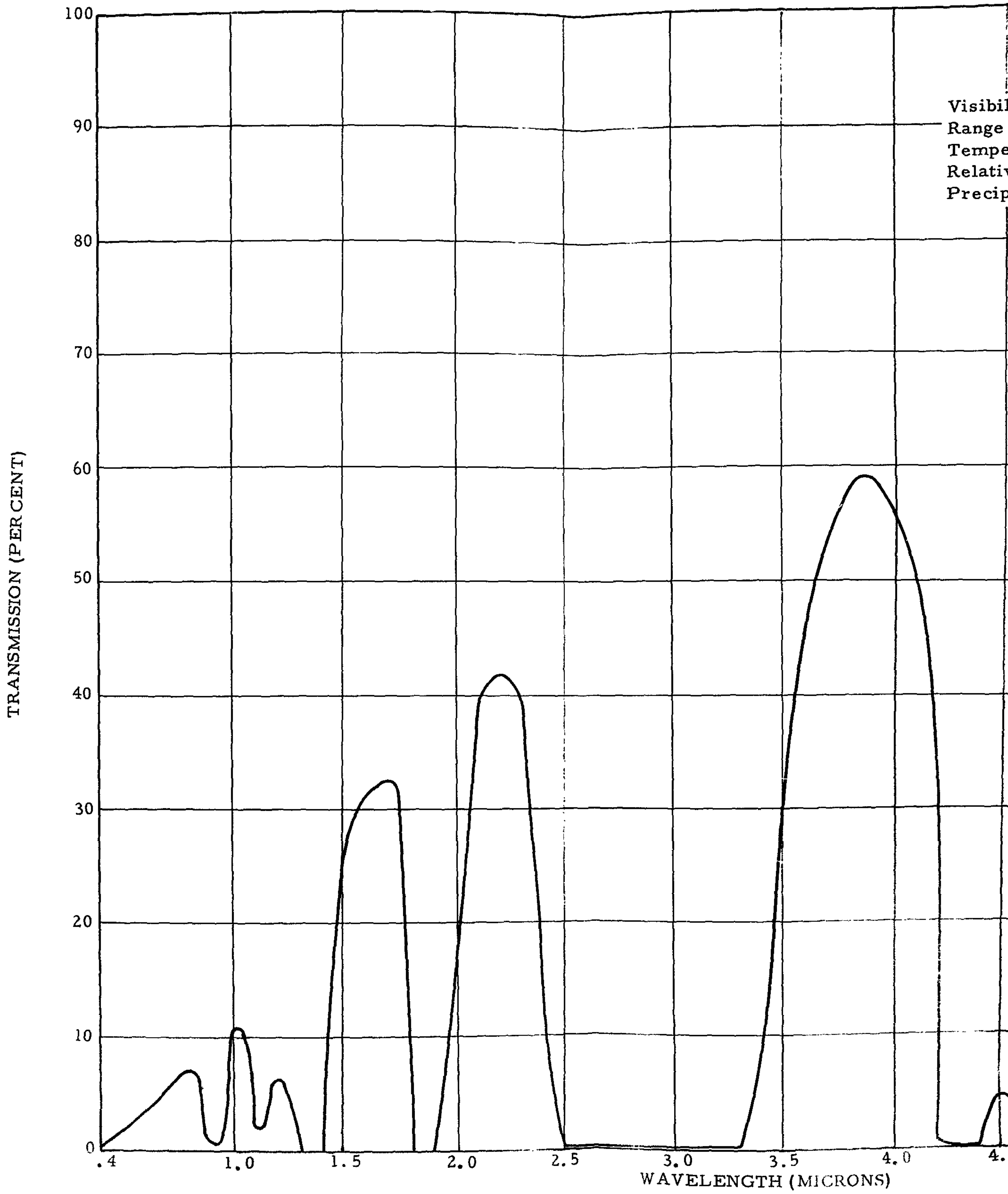

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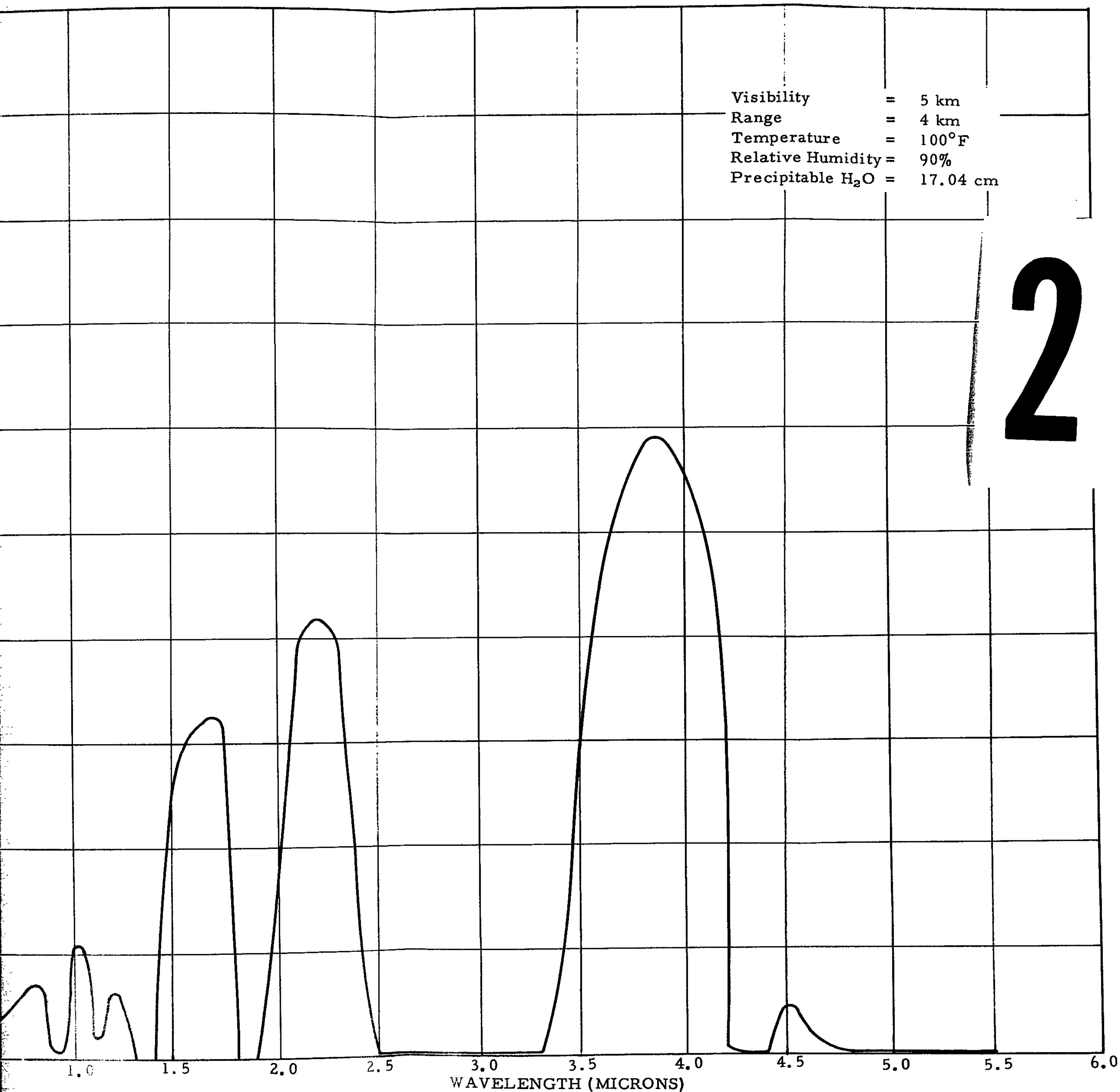

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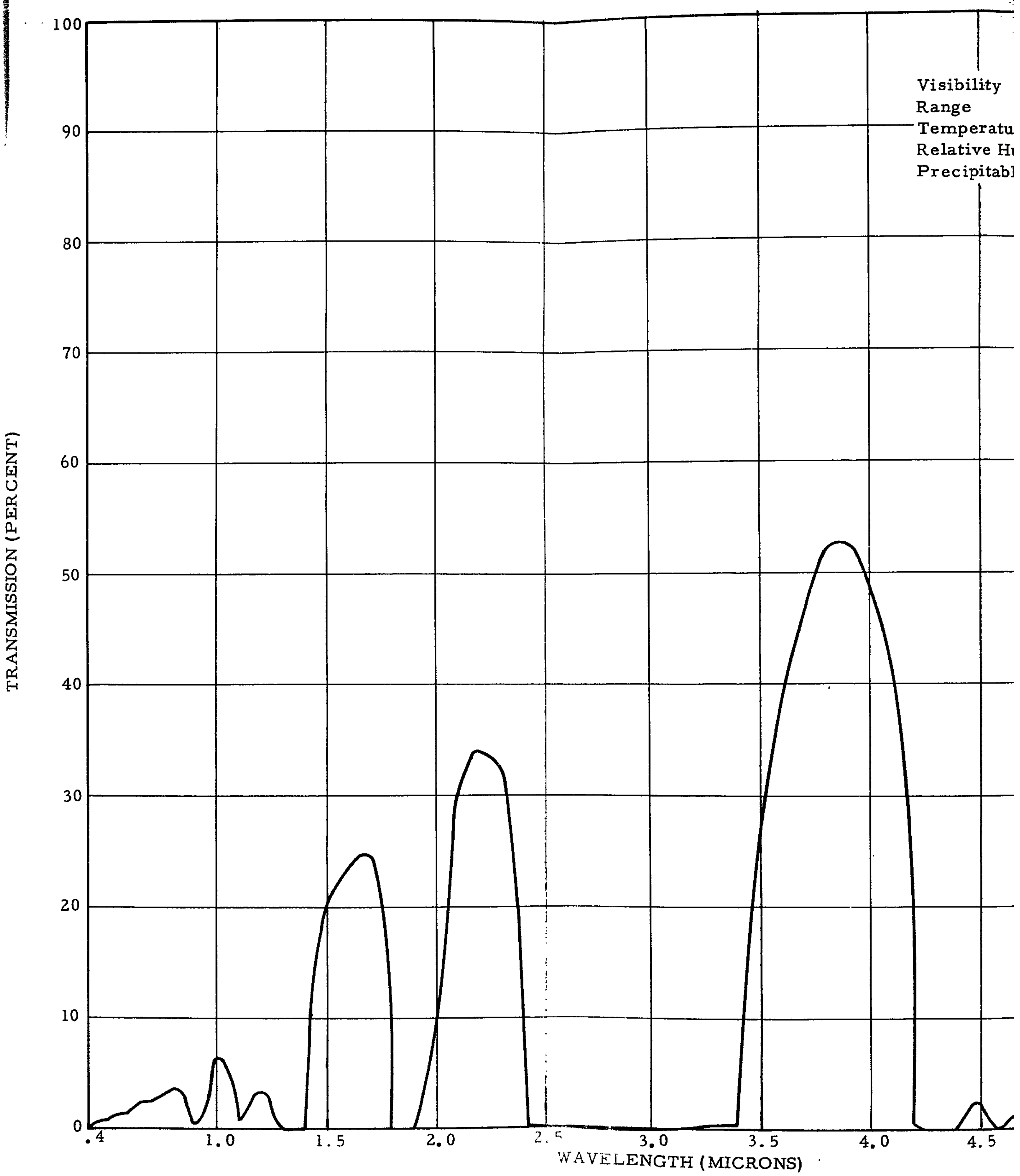

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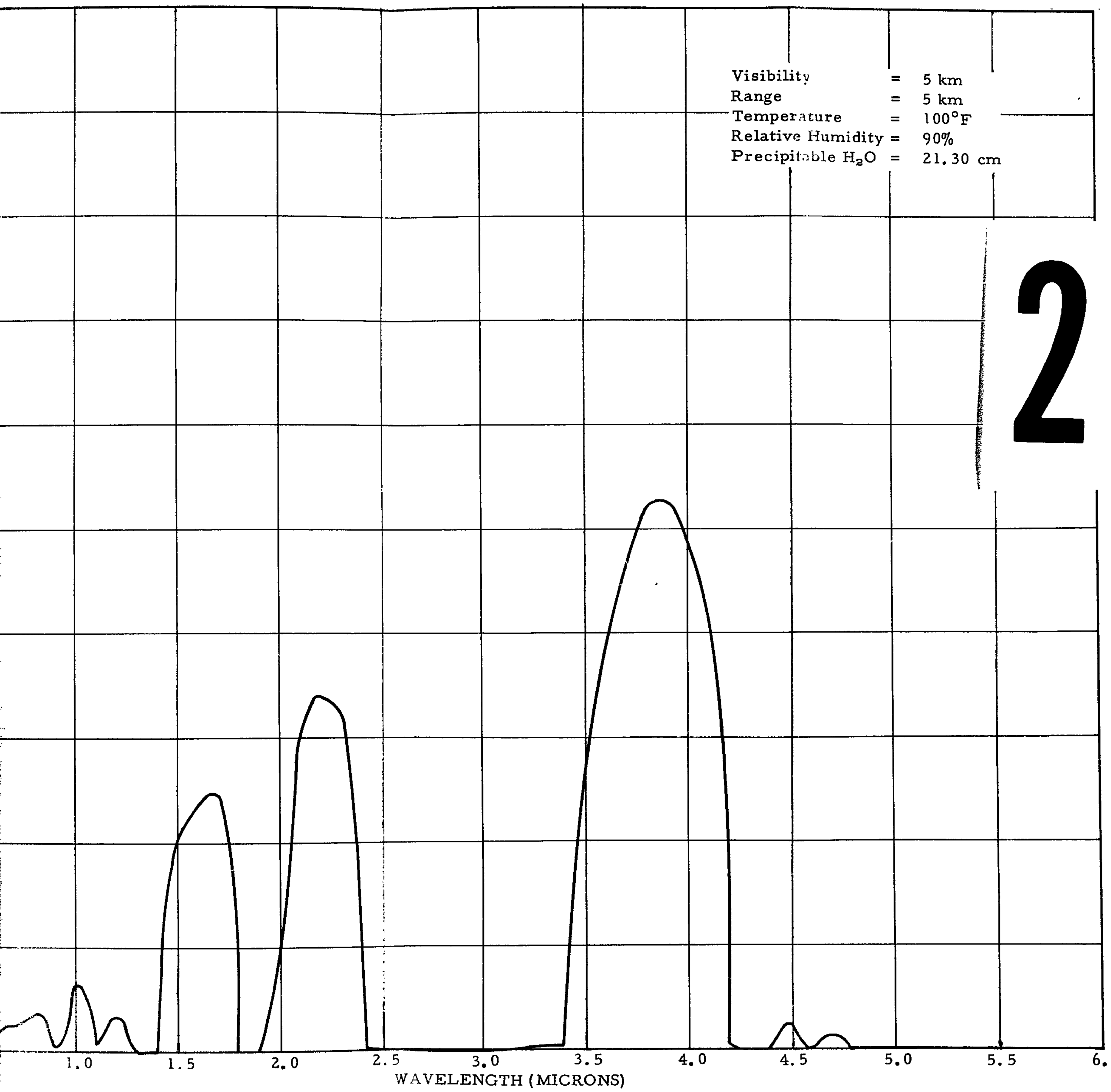

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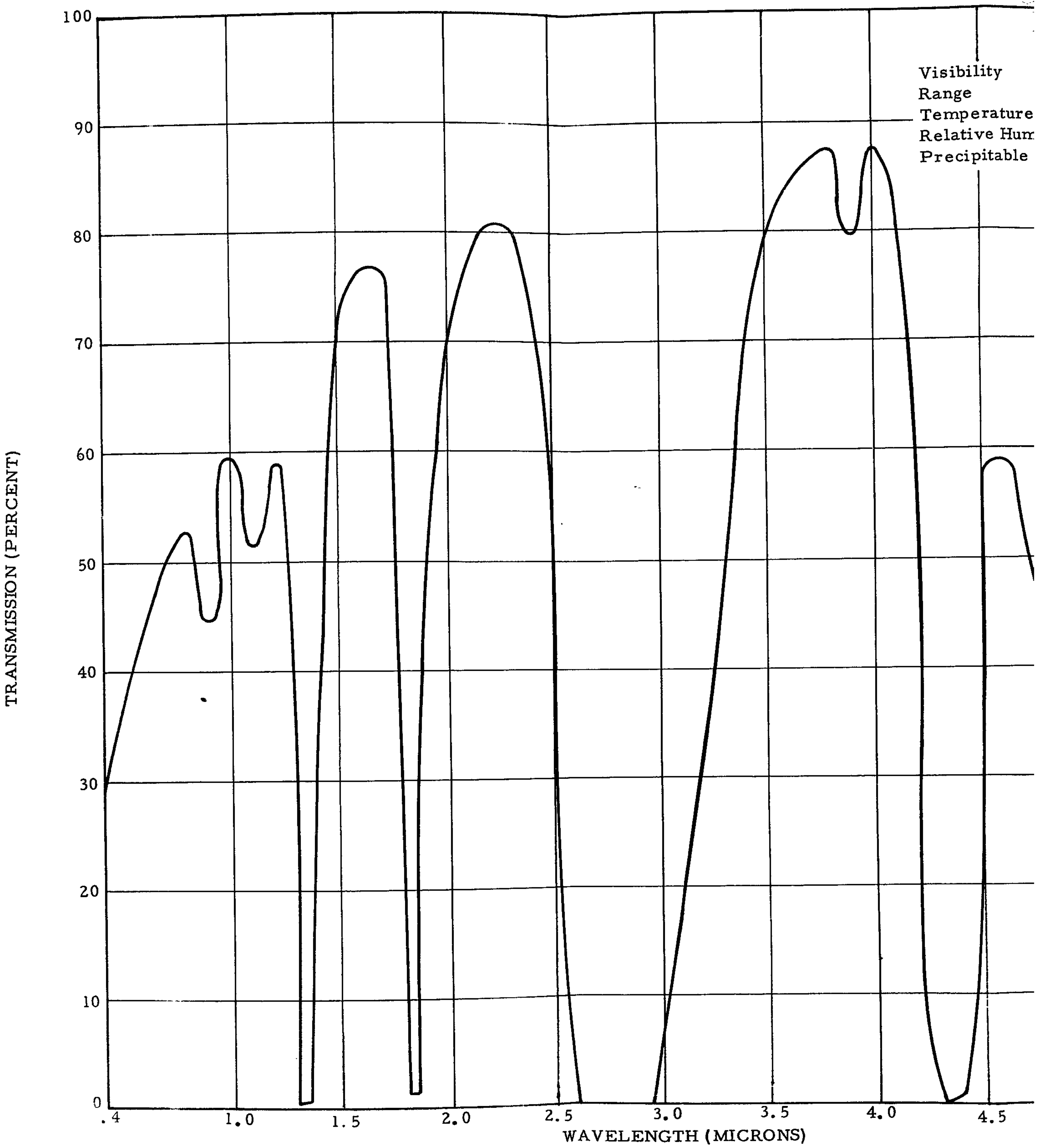

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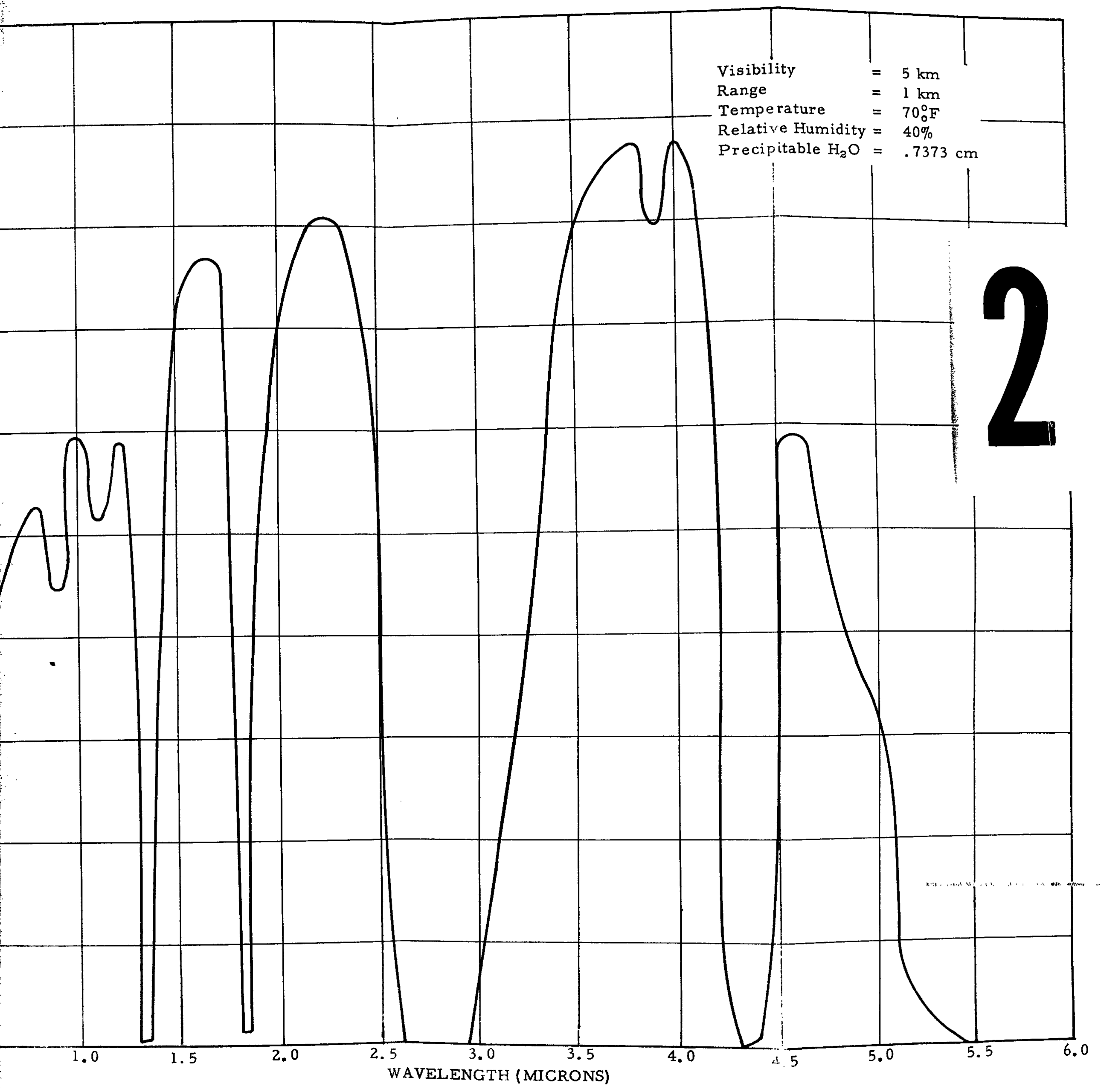

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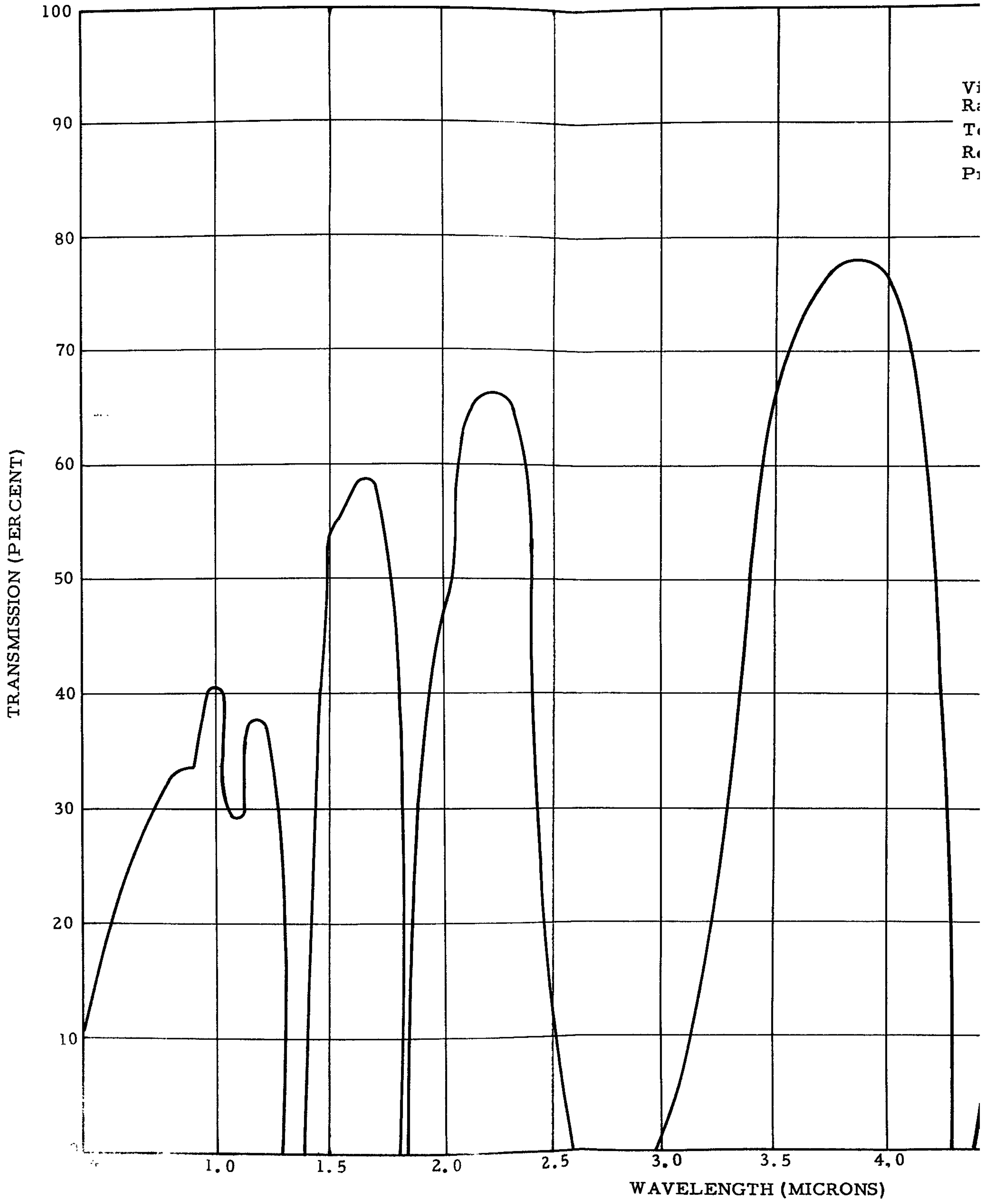

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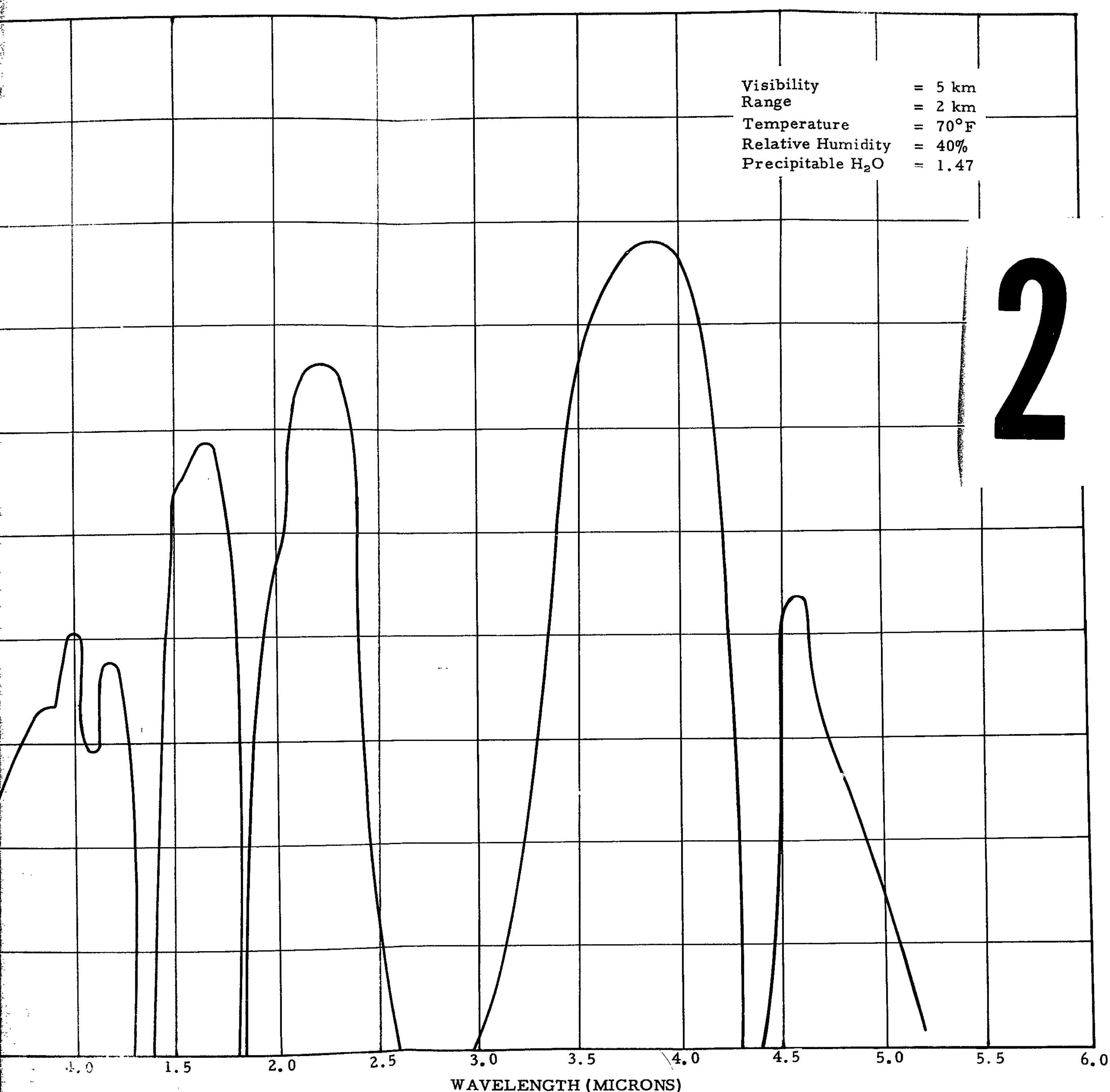

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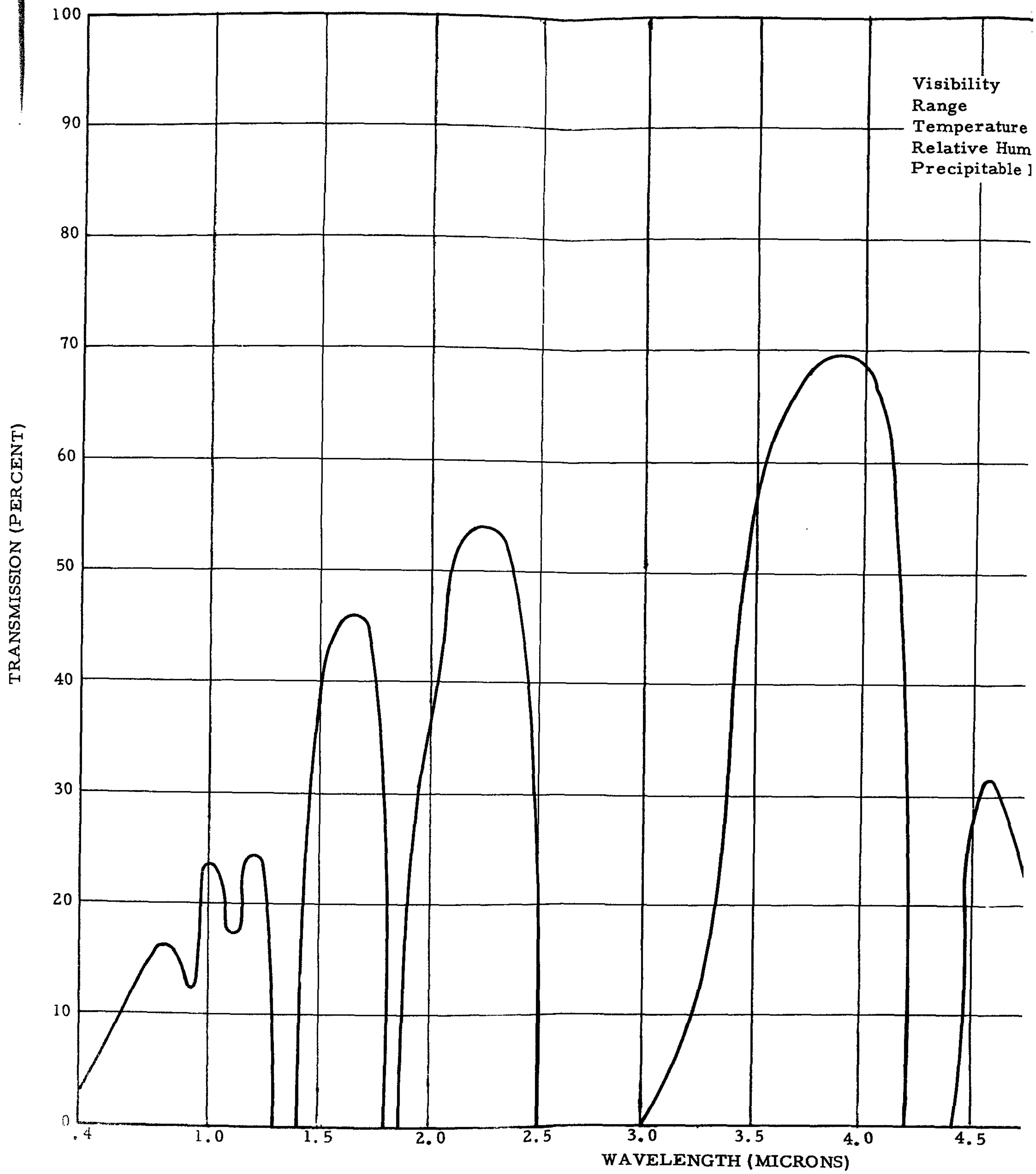

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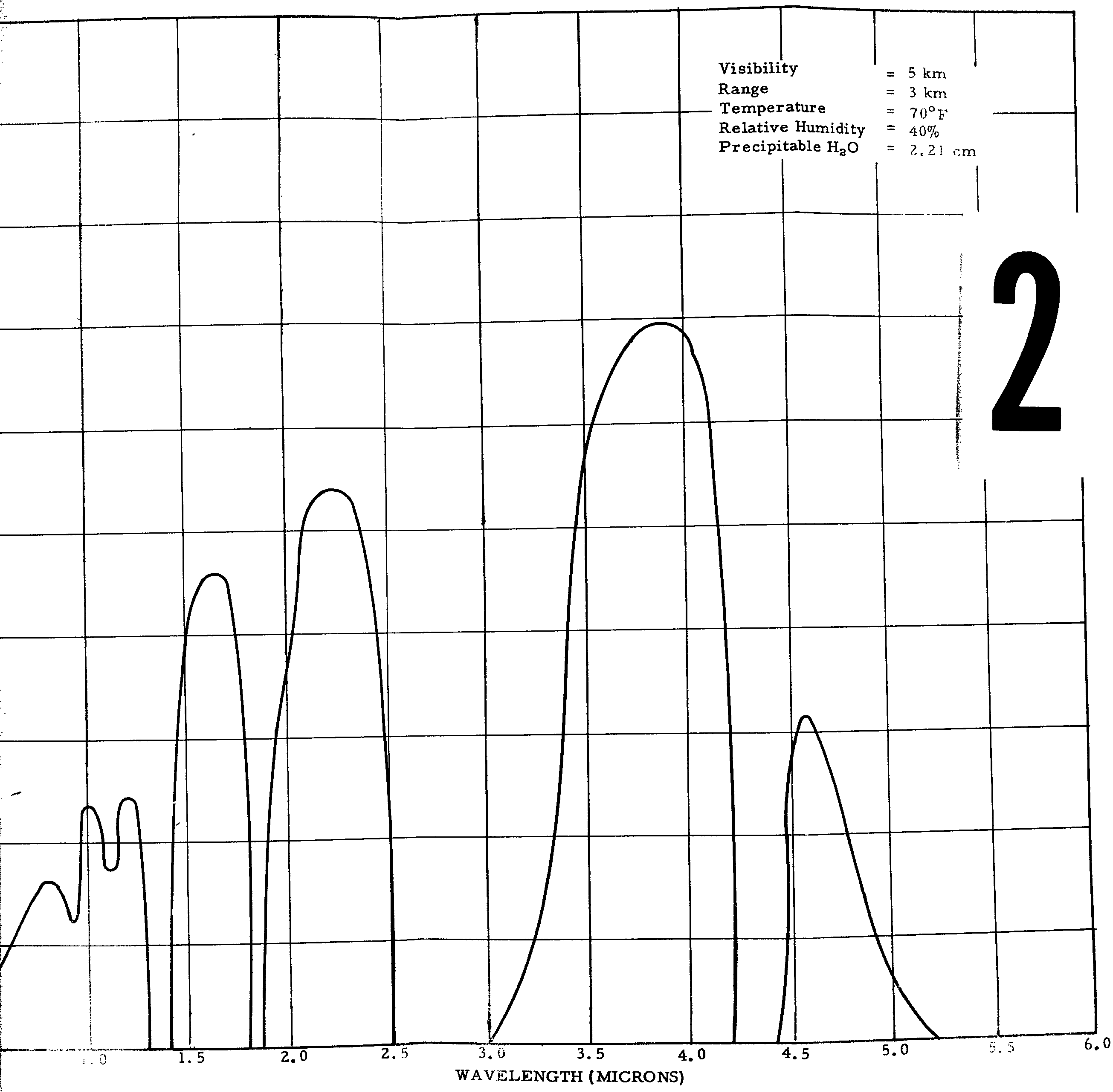

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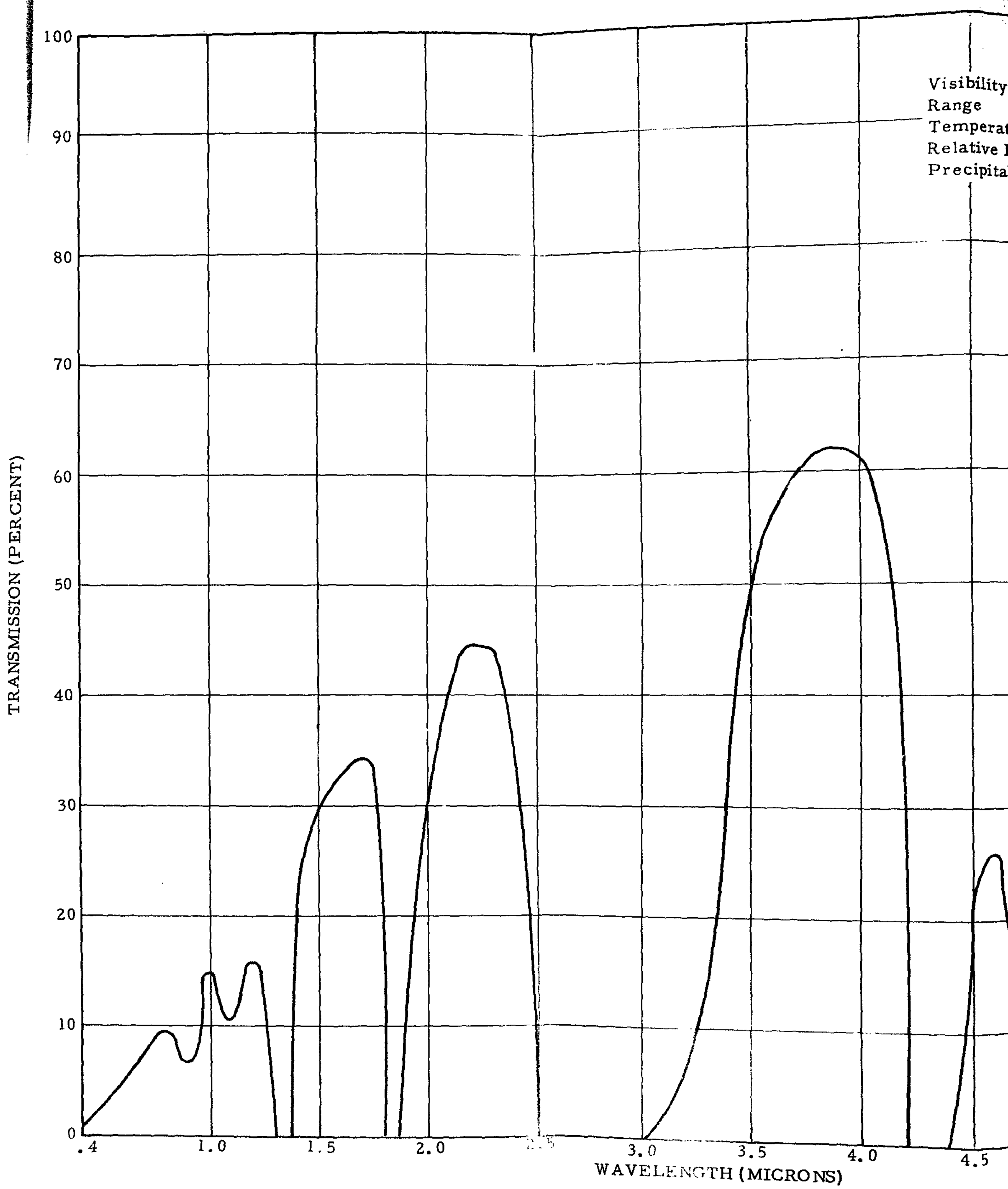

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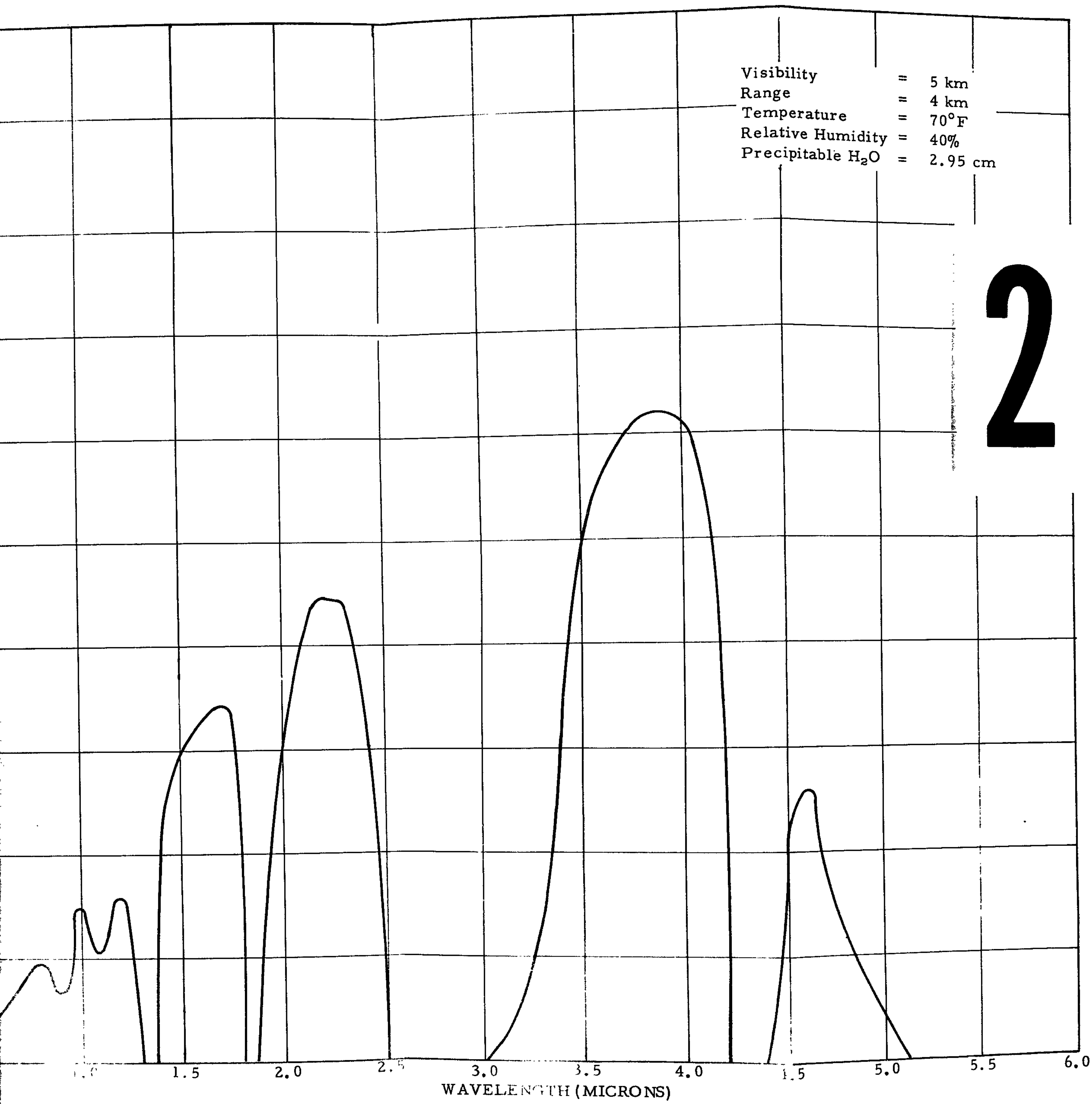

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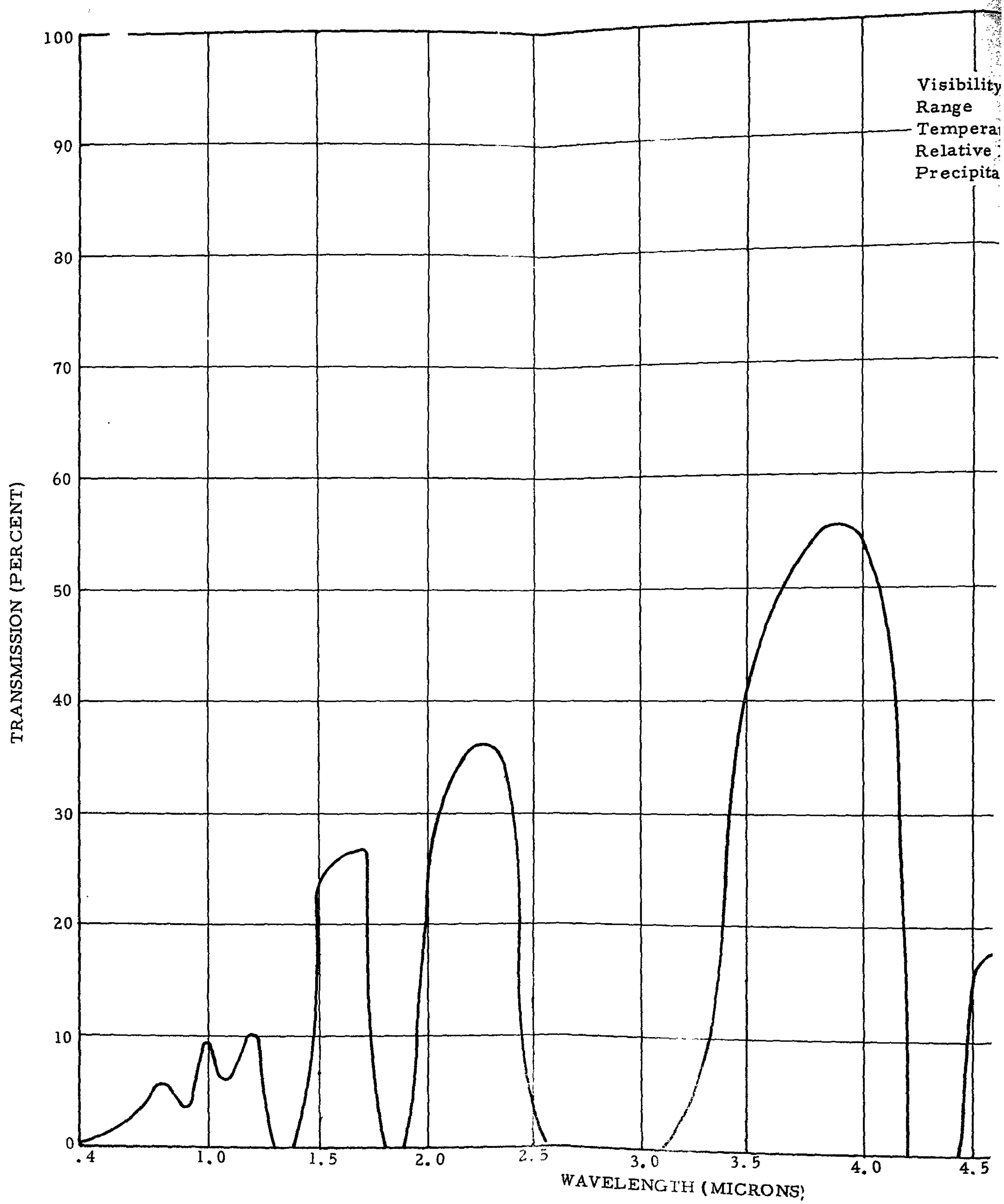

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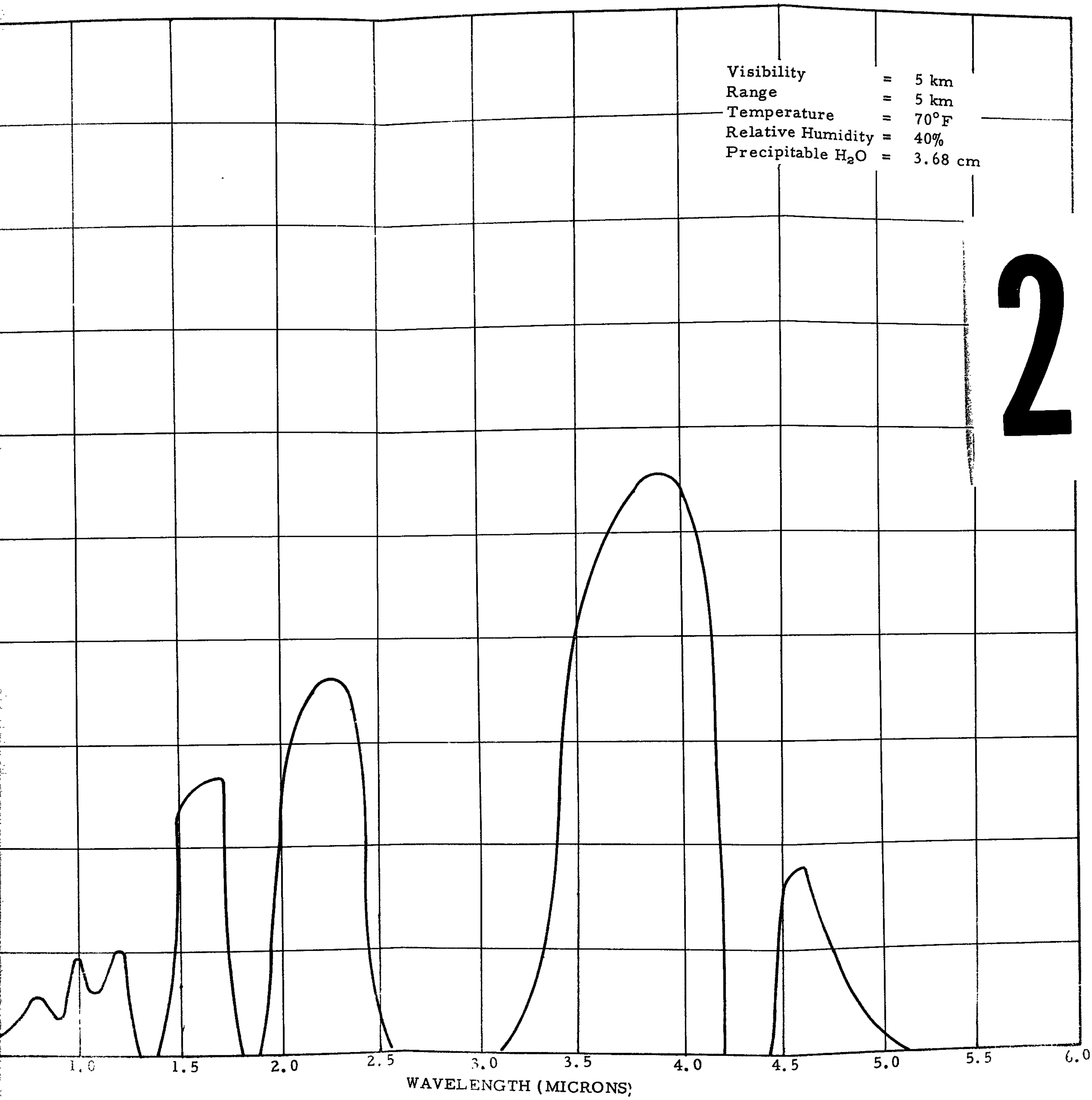

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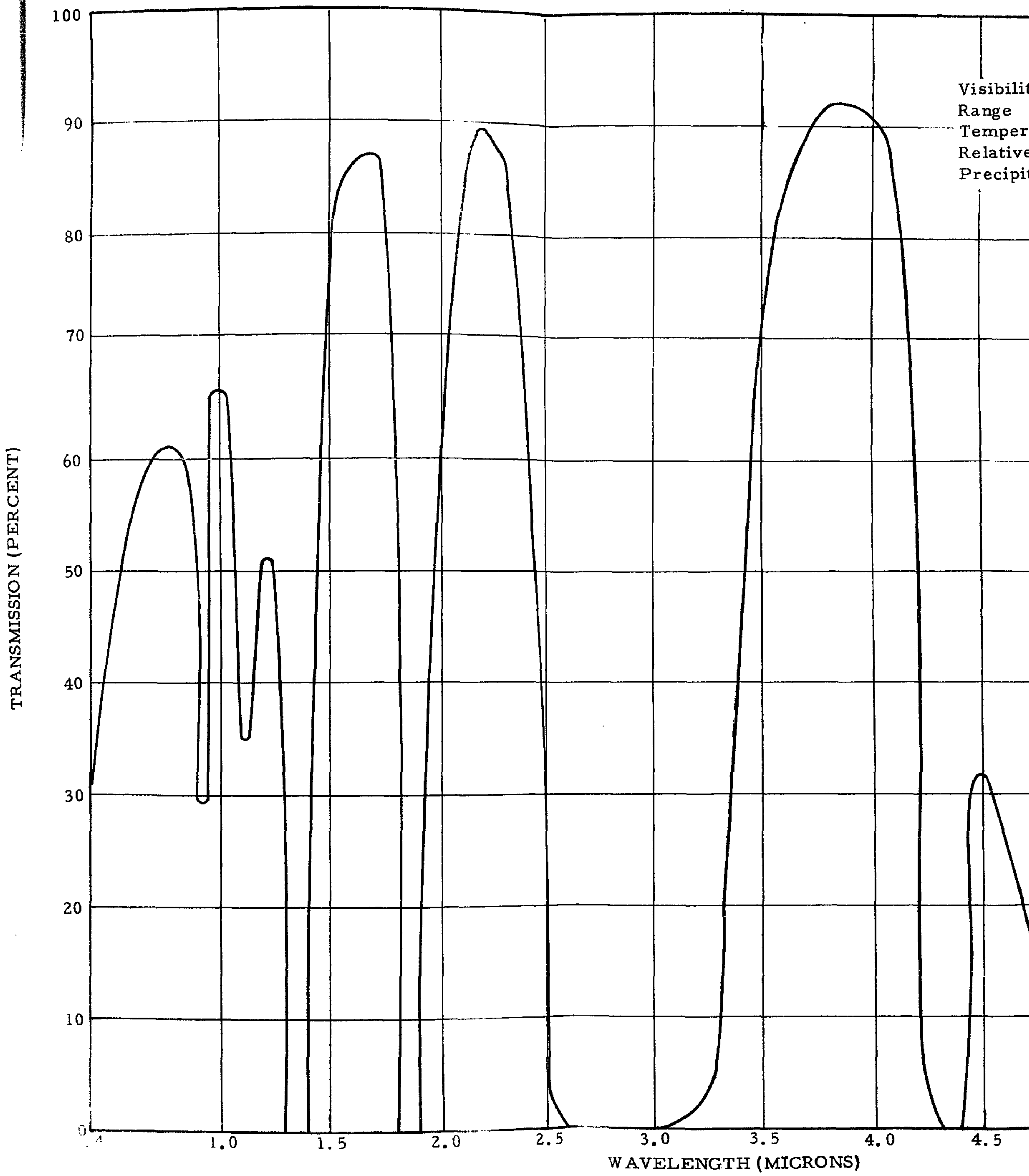

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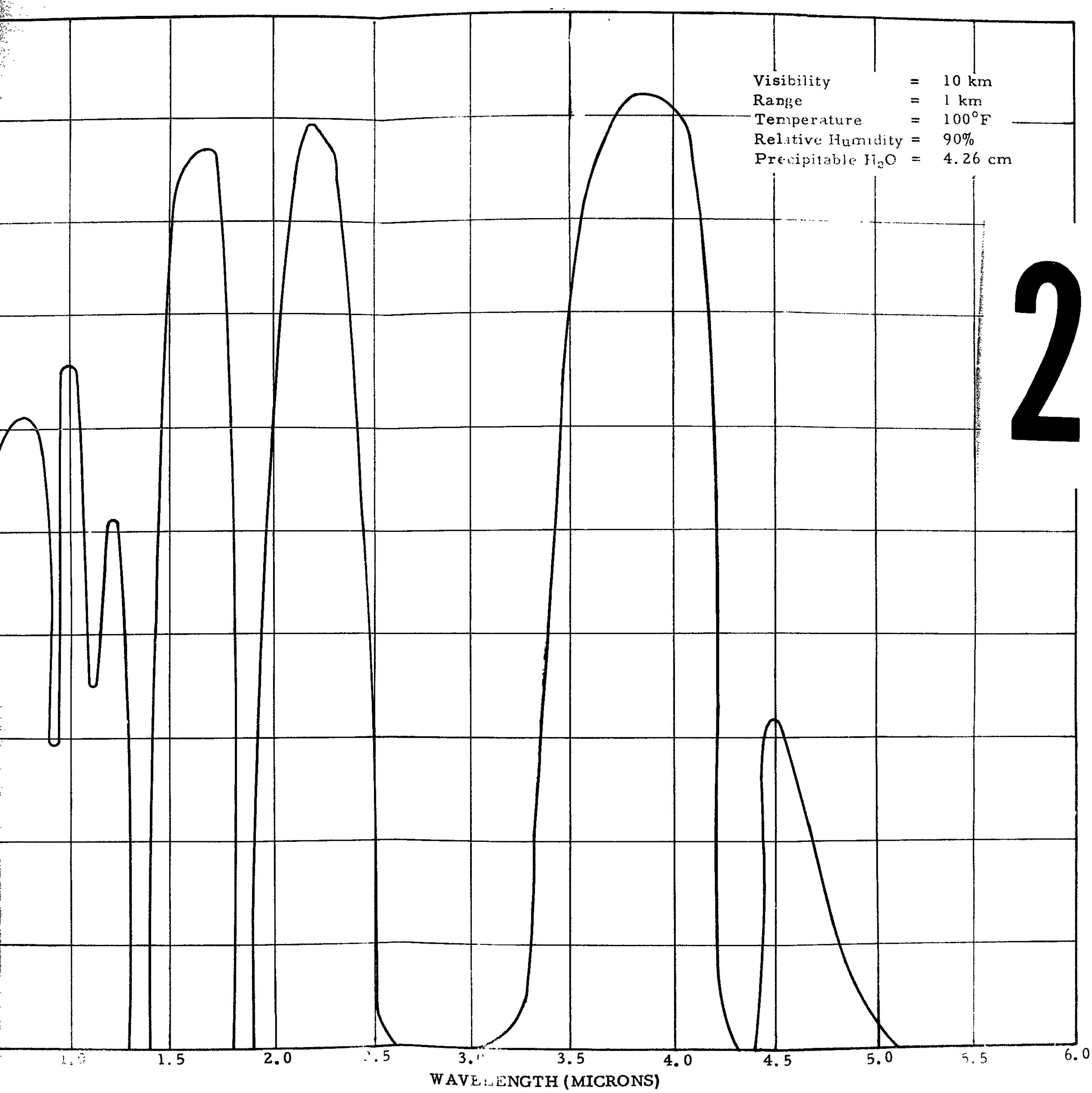

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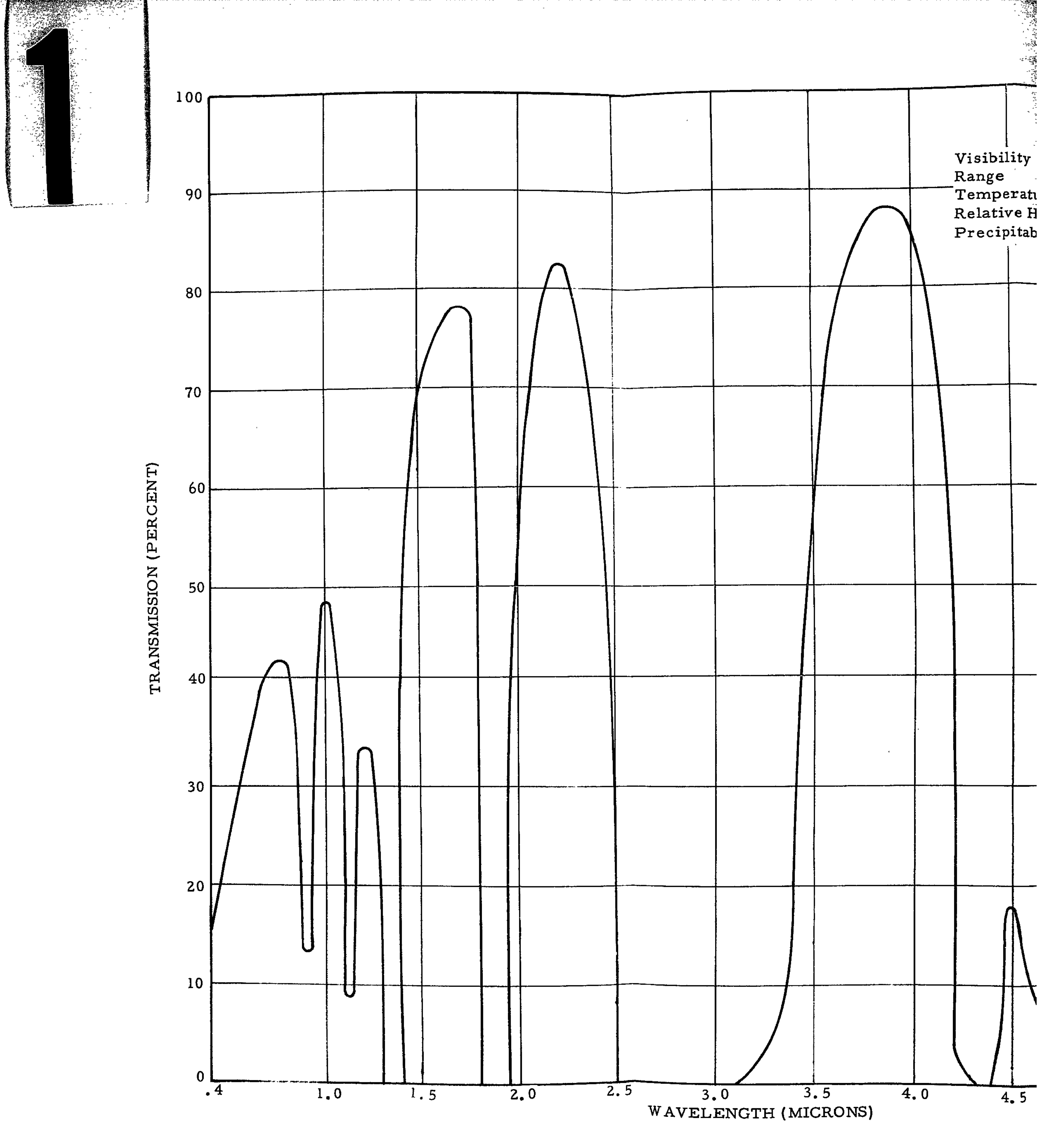

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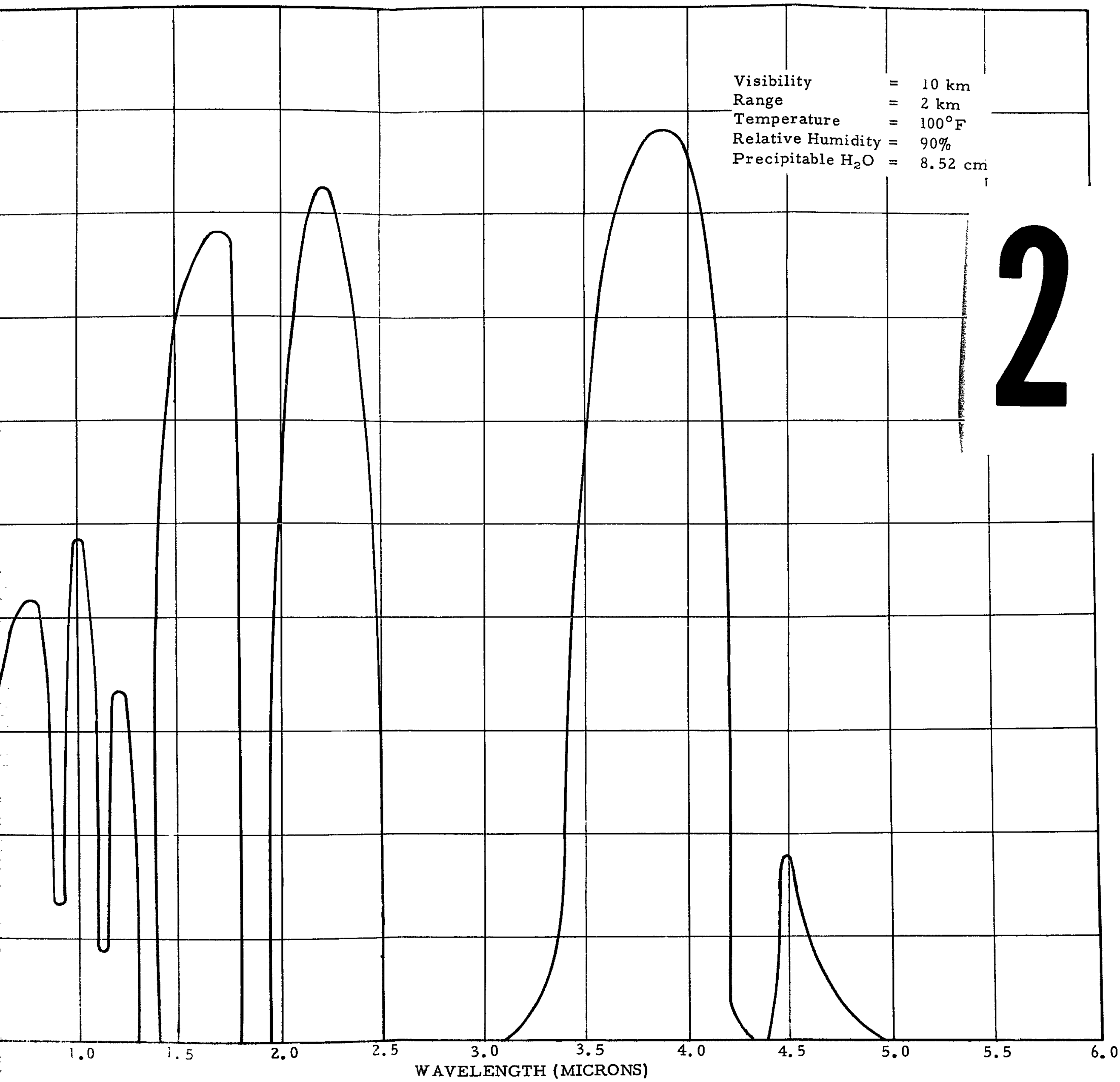

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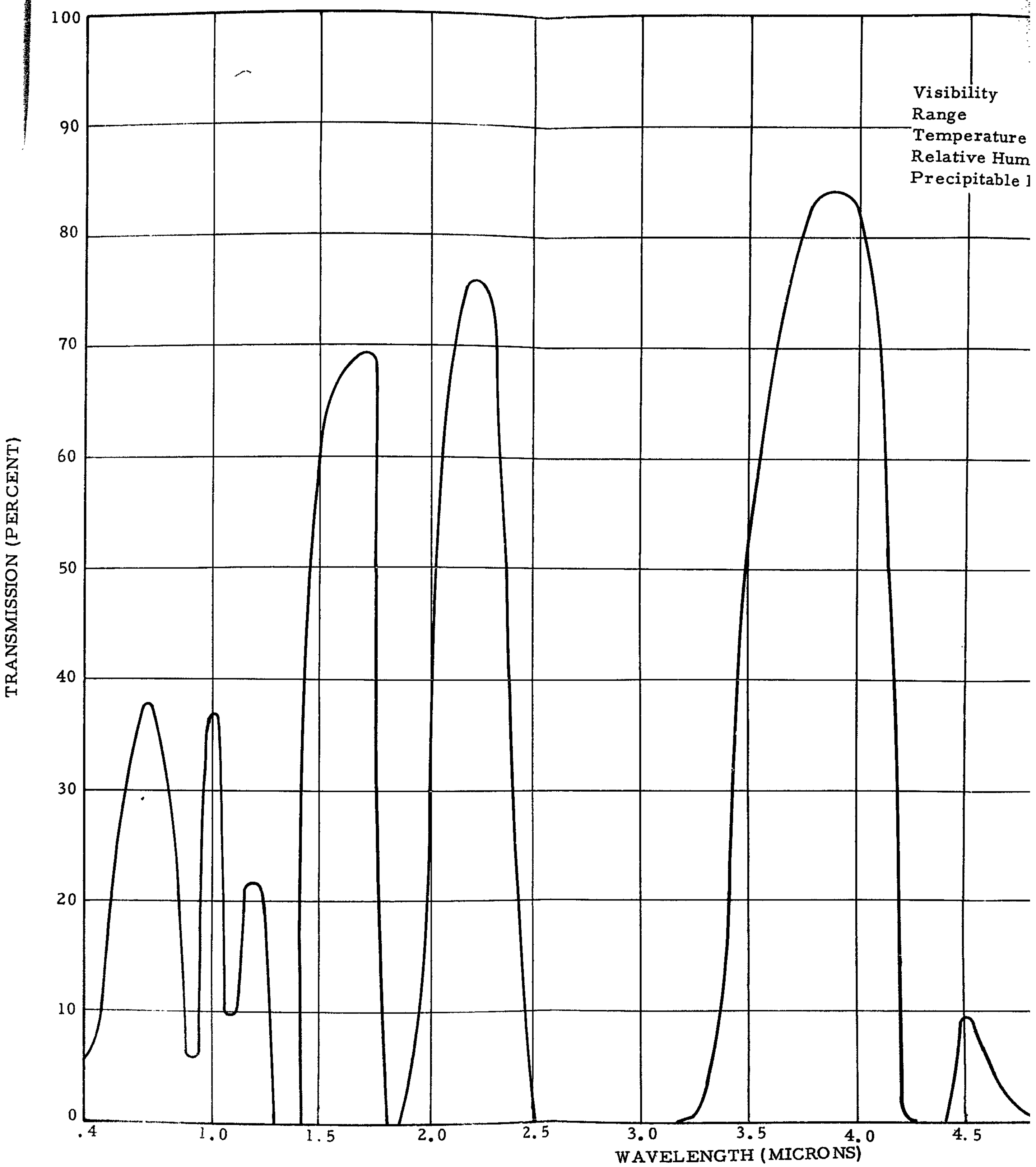

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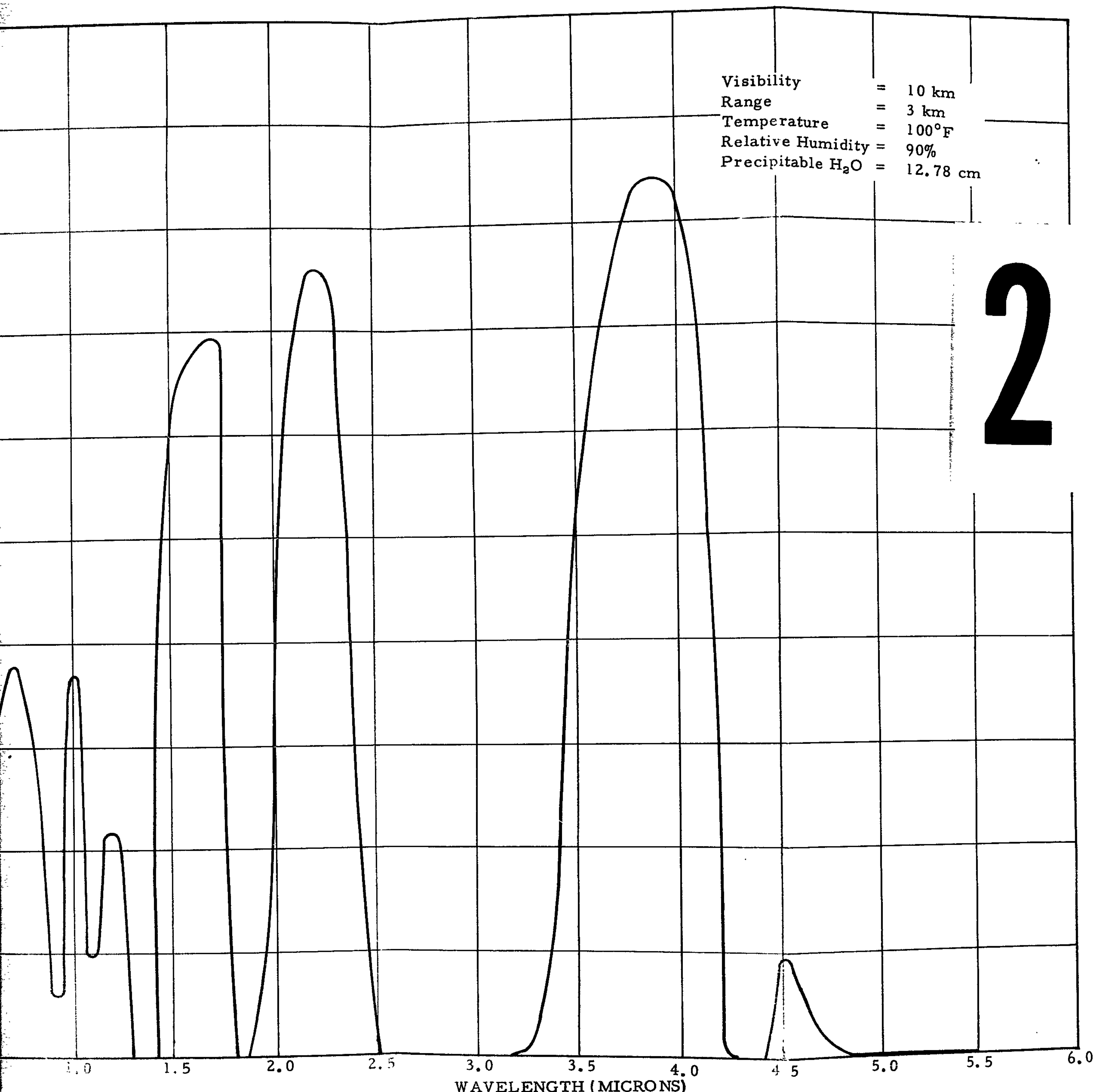

Figure 19. ATMOSPHERIC TRANSMISSION CURVE

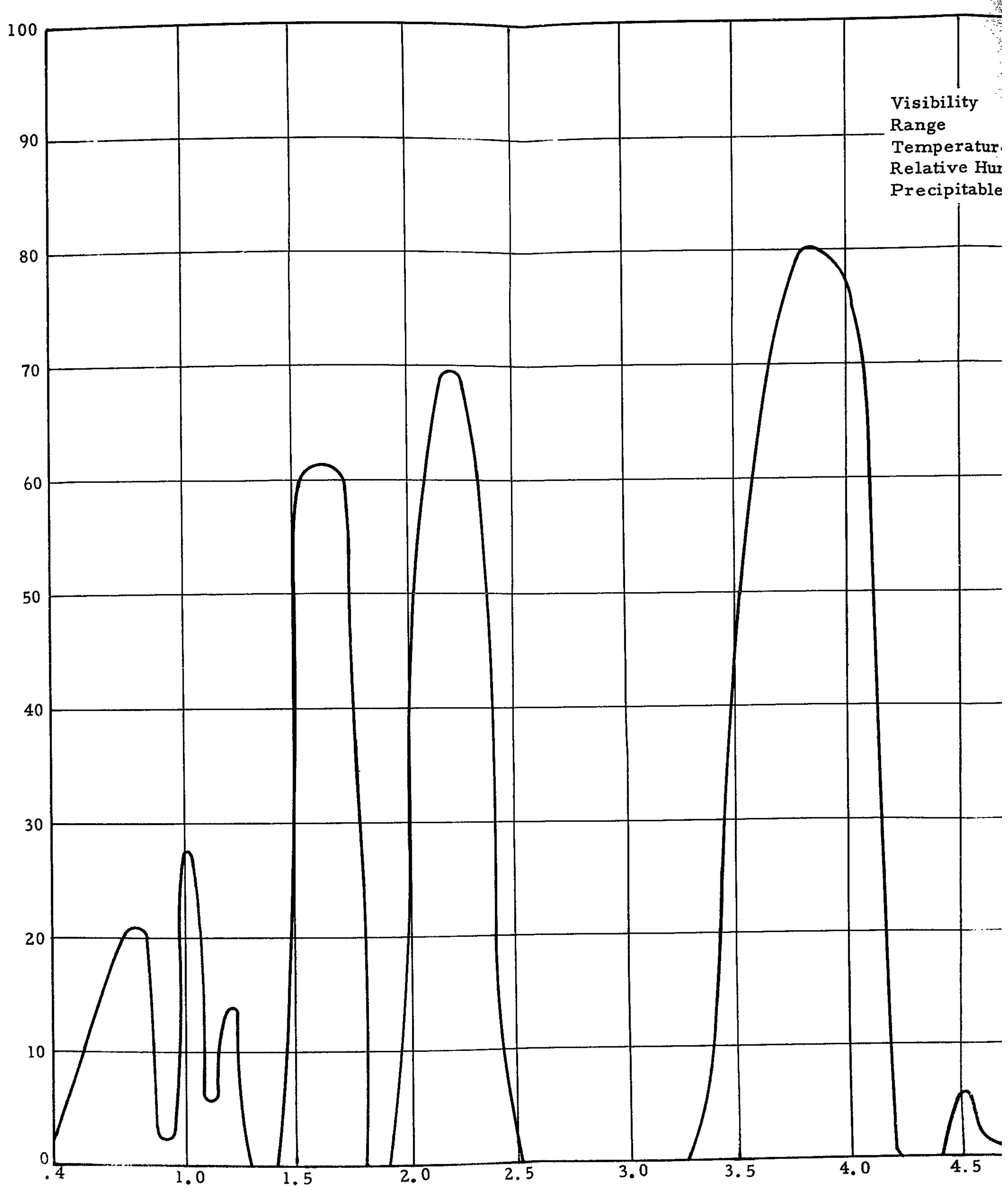

Figure 20. ATMOSPHERIC TRANSMISSION CURVE

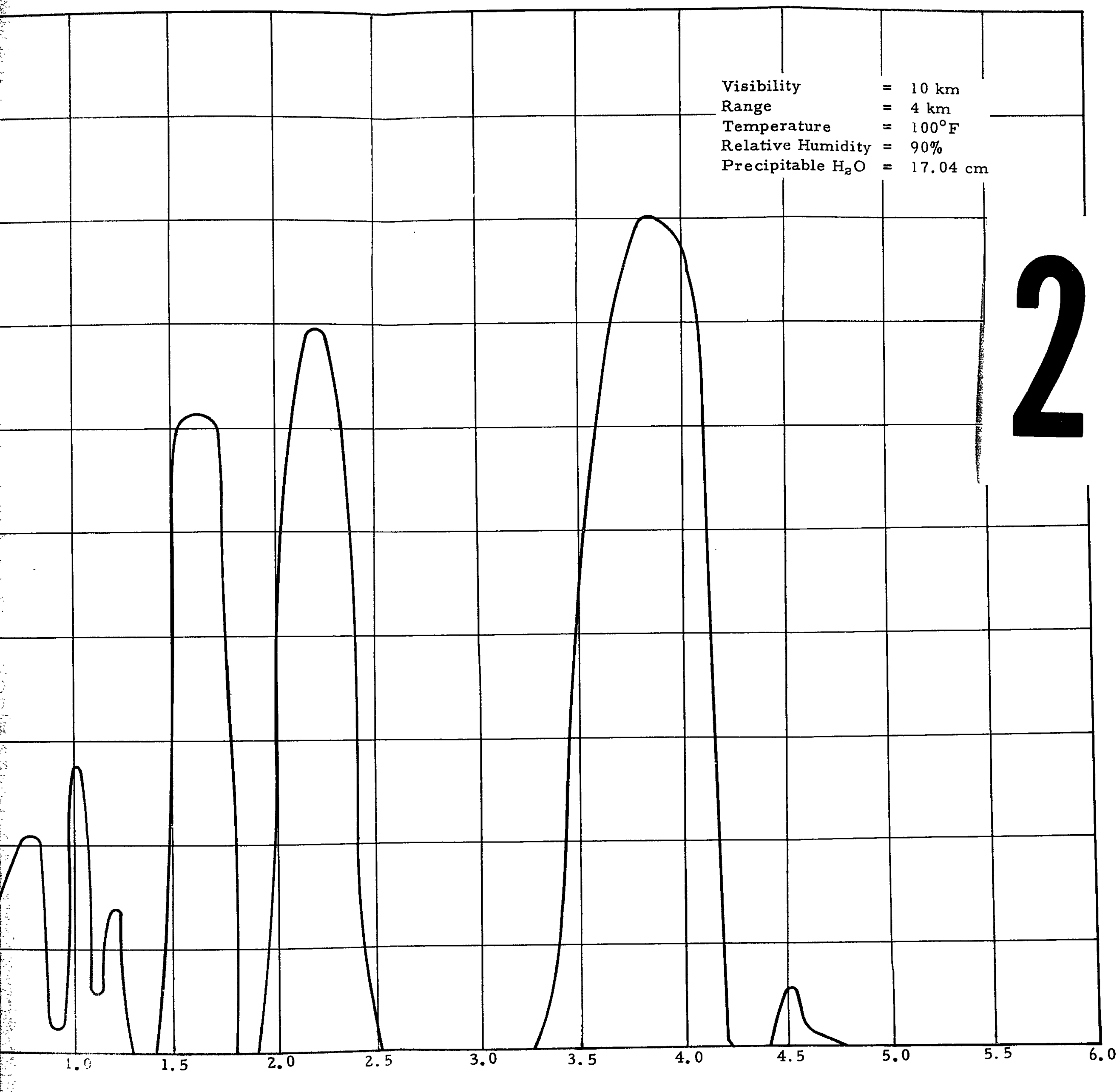

Figure 20. ATMOSPHERIC TRANSMISSION CURVE

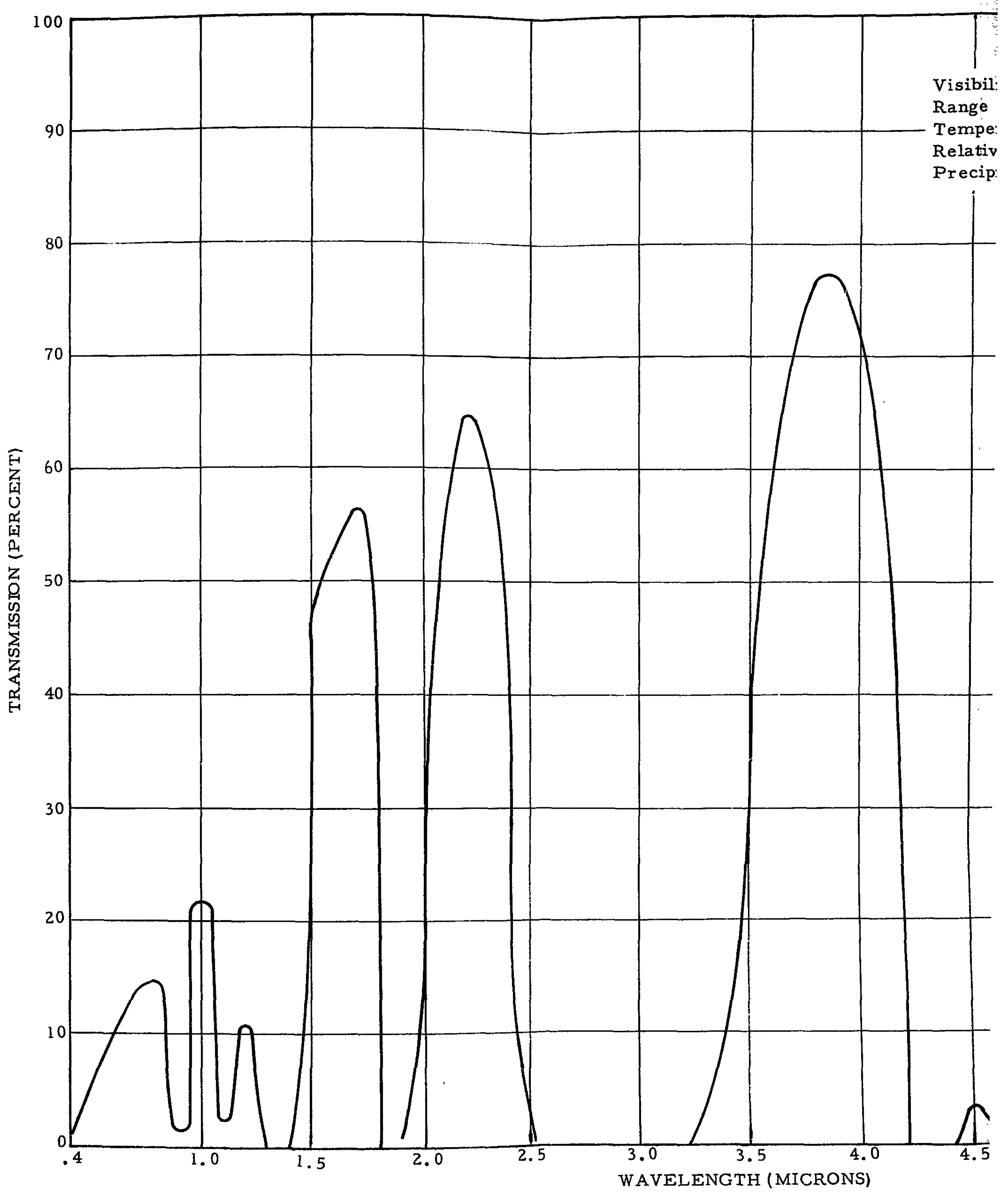

Figure 21. ATMOSPHERIC TRANSMISSION CURV

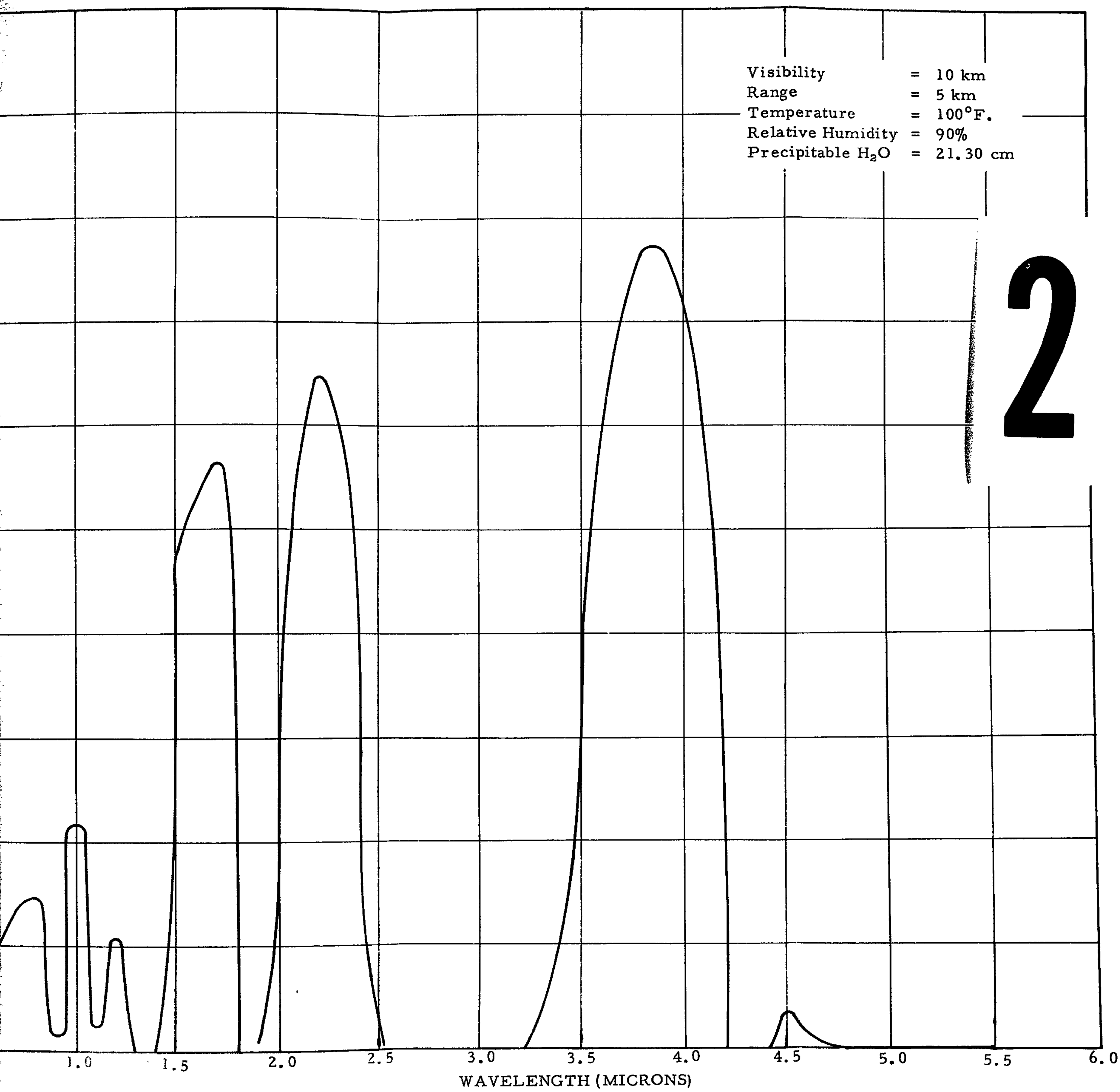

Figure 21. ATMOSPHERIC TRANSMISSION CURVE

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APPROVED:

N. J. MANGUS
Chief, Electro Optical Branch
Electromagnetics Laboratory

D. E. ROWE
Director, Electromagnetics Laboratory

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